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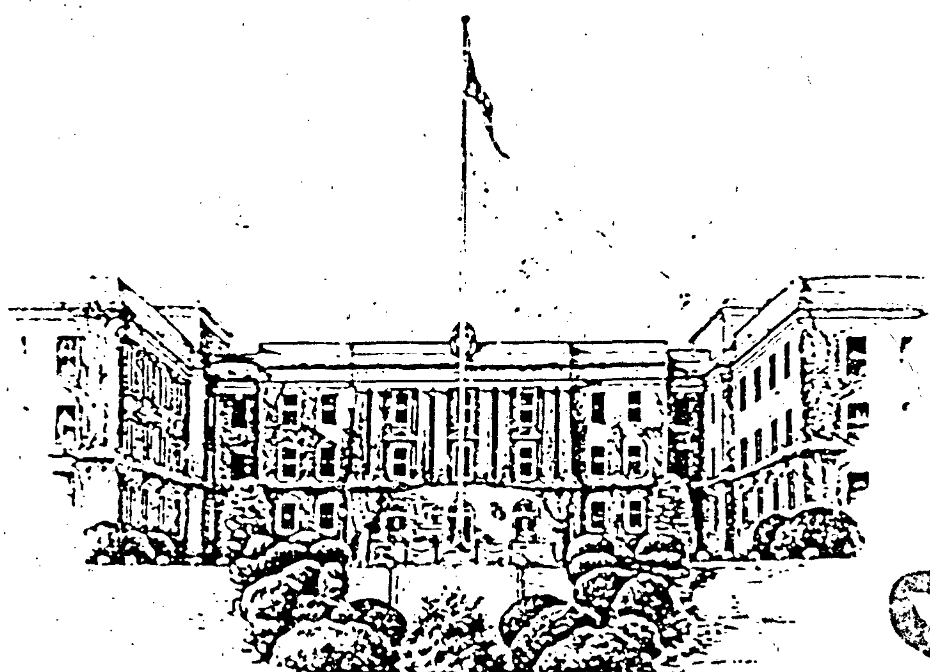
Human Performance in Continuous/Sustained Operations and the Demands of Extended Work/Rest Schedules: An Annotated Bibliography



DIVISION OF NEUROPSYCHIATRY

Walter Reed Army Institute of Research

Washington, D.C. 20307-5100

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The performance of workers under conditions of sustained or continuous work is a particularly important topic to the military services. Available research data on the topic are scattered throughout diverse printed sources, many of which are difficult to locate. This annotated bibliography lists 399 references containing research data, conceptual position papers and different methodological approaches to studying human performance in continuous/sustained operations and extended work/rest schedules. The time frame covered in the references is from 1940 to 1985.

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Human Performance in Continuous/Sustained Operations and the Demands of Extended Work/Rest Schedules: An Annotated Bibliography

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Catherine A. Loveless is now at the National Institute of Health, Bethesda, MD.

INTRODUCTION

Personnel at the Walter Reed Army Institute of Research (WRAIR) compiled this annotated bibliography on human performance in continuous/sustained operations and the demands of extended work/rest schedules as a source document for our research colleagues and for the many military decision makers presently concerned with these topics. We began with a primary interest in the psychological literature that might apply to the performance of military personnel engaged in continuous work for sustained periods of time -- durations that exceed a "normal duty day" -- long enough to involve some individual sleep deprivation.

We did not include references to industrial shift work schedules, sleep deprivation, sleep discipline, circadian and biological rhythms, jet lag, exercise physiology or fatigue per se. However, since all of these are involved to some degree in any study of sustained work, many references contain elements of these topics. We have also included select cross references to these topics. We included multi-disciplinary articles that described different methodological approaches to studying not only the psychological, but the physiological, biochemical and ergonomic factors relating to sustained work as well.

The references cited within were obtained from diverse and widely scattered sources. We searched the U.S. Defense Technical Information Center (DTIC), the National Technical Information Service (NTIS), the open psychological and biomedical literature journals and the file drawers of numerous research colleagues for appropriate references. We only included foreign language reports if we had an English translation available. We did not include references containing a security classification. The time frame covered is from 1940 to 1985.

Most of the abstracts cited came directly from the authors; some were taken from journal articles; some were modified by us, and others we wrote as we compiled this bibliography. To us, all of the articles should in some way be of interest to those who do research on sustained performance or continuous operations. Some of them can be categorized as reviews, or conceptual descriptions of problem areas. Some offer alternative methodological approaches. Many offer fairly complete data, while others offer only sketchy or incomplete data. For the sake of completeness, and because the ideas advocated in some paper listed here may one day spur more good research on the topic, we have included them all.

Users of this bibliography are encouraged to submit copies of additional applicable references to us at WRAIR for consideration in research and for reference in subsequent publications related to these topics.

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1. Adams A. H., Huddleston H. F., Robson B. M., & Wilson R. V. (1972). Some effects of sleep loss on a simulated flying task. (RAE Report No. 72168). Farnborough, England: Royal Aircraft Establishment.

Twelve RAF pilots performed a simulated flying task. One group of 6 pilots performed after loss of a full night's sleep. The second group of 6 pilots participated after loss of part of a night's sleep. Integrated tracking error scores showed no significant differences between the two groups. Peripheral light detection was significantly impaired by one night's sleep loss. Card-sorting and digit memory tasks showed no effects.

2. Adams J.T. (1967). Fatigue in helicopter aircrews in combat. In: Aeromedical aspects of helicopter operations in the tactical situation: Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting, May, 1967 in Paris, France. (NATO/AGARD Report No. CP-24). London: Technical Editing and Reproduction Ltd. (DTIC No. AD 667-210).

It is generally felt by dual-rated pilots that a higher level of physical coordination and attention coupled with less opportunity to relax are required in helicopter as compared to fixed wing flying. This article deals with the newer roles that military helicopters are being cast in with emphasis on the requirements being placed on the aircrews. Material for discussion of combat related problems is largely based upon experience. Nevertheless, analogies exist and may be relied upon to lend a broader perspective where future problems are to be anticipated.

3. Adams O. S., & Chiles W. D. (1960). Human performance as a function of the work-rest cycle. (WADC Report No. 60-248). Wright-Patterson Air Force Base, OH: Wright Air Development Center, Behavioral Sciences Laboratory. (DTIC No. AD 240-654).

This study was designed to investigate the effect on performance of four different work-rest period schedules (2

hours on duty and 2 hours off duty, 4 on and 4 off, 6 on and 6 off, and 8 on and 8 off) followed over a period of 96 consecutive hours. The subject sample consisted of 16 male college students with 4 subjects being assigned to each of the four work-rest period schedules. Performance was measured by means of a battery of psychomotor tasks involving arithmetic computation, pattern discrimination, monitoring, and vigilance. Additional data were obtained from information recorded in an experimenter's logbook and from responses to a questionnaire administered at the end of testing.

4. Adams O. S., & Chiles W. D. (1961). Human performance as a function of the work-rest ratio during prolonged confinement. (ASD Report No. TR 61-720). Wright-Patterson Air Force Base, OH: Aeronautical Systems Division.

This study investigated the feasibility of using a 4-hours-on-duty and 2-hours-off-duty schedule in the operation of advanced aerospace systems. Two B-52 bomber combat-ready crews were confined for 15 days in a simulated advanced system crew compartment and were tested with a battery of five performance tasks and four psychophysiological measures. Data obtained during two 15-day testing periods are summarized. Additional performance data obtained from five studies using college student subjects are presented in appended sections of this report. Results are based on four 96-hour investigations (two with a 4-on and 2-off schedule and two with a 6-on and 2-off schedule) and one 120-hour control group study (4 hours per day, 5 days per week, for 6 weeks). With proper control of selection and motivational factors, crews can work effectively for periods of at least two weeks and possibly longer using a 4-hours on and 2-hours off work-rest schedule.

5. Ainsworth L. L., & Bishop H. P. (1971). The effects of a 48-hour period of sustained field activity on tank crew performance. (HumRRO Report No. TR-71-16). Alexandria, VA: Human Resources Research Organization. (DTIC No. AD 731-219).

A 48-hour field experiment was conducted to determine the effects of sustained activity on the performance of tank crews in communication, driving, surveillance, gunnery, and maintenance activities. Only moving surveillance and some driving activities showed statistically significant performance deterioration over a 48-hour period of work without sleep, but these decrements were not of practical significance. The diurnal rhythm of the subjects did not affect performance significantly. The results of the experiment support the broad conclusion that tank crews using present equipment can maintain operational proficiency during 48 hours of sustained activity and that changes in unit organization or tactical doctrine are not necessary to accomplish continuous operations.

6. Akerstedt T. (1976). Interindividual differences in adjustment to shift work. In: Proceedings of the 6th Congress of the International Ergonomics Association "Old World, New World, One World" at the University of Maryland, College Park, MD. (pp. 510-514). Stockholm, Sweden: Karolinska Sjukhuset. (NTIS No. PB 261 295).

Three hundred and twenty 3-shift workers, 30 2-shift workers and 30 day workers filled out a questionnaire on work hours and well-being. For 3-shift workers highest ratings of well-being were reported for the afternoon shift, followed by morning, and night shifts. Two-shift workers gave ratings identical to those of the 3-shift workers on corresponding shifts. Multivariate analysis showed that neuroticism, mental demands on the job and, to some extent, also housing standards accounted for variance in well-being on the night shift. When sleep length was used as the dependent variable, the most important predictors were age and experience with shift work. Finally, it was found that, above the age of 45, well-being on the night shift decreased with increased experience at shift work. In younger age groups no relations of this kind were found. (Age was held constant in all analyses.) The relations found may indicate the existence of a process of accumulation of costs of adjustment starting around the age of 45.

7. Akerstedt T., Froberg J., Torsvall L., Levi L., & Zamore K. (1977). Shift work and well-being. Stockholm, Sweden: Karolinska Sjukhuset Institute, The Labcratoy for Clinical Stress Research. (NTIS No. PB 299-093).

The article is a review of the results of an interdisciplinary study on shift work and health. It is based on several investigations on circadian rhythms in psychophysiological activation during 72 hours of sleep deprivation, activation in permanent night workers, in workers alternating between night and day work, and in day workers entering shift work for the first time. Several transverse questionnaire investigations estimate the prevalence of shifts in Sweden, the relations between phase in the shift cycle and indicators of psychosomatic and social complaints, and the relation between complaints and possible predictors.

8. Allnutt M. F. (1970). Sleep at unusual hours, drugs and subsequent performance. In A. J. Benson (Ed.), Rest and activity cycles for the maintenance of efficiency of personnel concerned with military flight operations: Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting, May 1970 at Oslo, Norway. (NATO/AGARD Report No. CP-74-70). London: Technical Editing and Reproduction Ltd.

If a pilot has to get up early in the morning to fly a long and difficult sortie, should he be given drugs to aid his sleep? This paper reports an experiment in which eight trainee pilots were sent to bed at 2000 hours, and then awakened at 0300 hours to spend the rest of the day carrying out performance tests. There were four experimental conditions: (1) no drug, (2) placebo, (3) mogadon, and (4) seconal. Each subject spent two nights under each condition. During every alternate 24-hour period of the three weeks for which the experiment lasted, the subjects were off duty and free to sleep as they pleased. In addition to objective measures of performance and subjective measures of mood and sleep, continuous EEG recordings were made throughout each "experimental" night.

Although EEG records showed all subjects obtained an adequate night's sleep, subjects rated their sleep as being better under both drug conditions than under the no drug condition. The drugs had no noticeable effect on a calculation task, and only slight effects on a vigilance task, these occurring in the later run of the day, 16-20 hours after the drugs had been taken.

9. Allnutt M. F., & O'Connor P. J. (1971). Comparison of encephalographic, behavioral and subjective correlates of natural and drug-induced sleep at atypical hours. Aerospace Medicine, 42, 1006-1010.

Eight trainee pilots retired to sleep under laboratory conditions from 2000 hours to 0300 when they were awakened to spend 8 hours performing 2 behavioral tests (calculation and vigilance). This regimen was repeated on alternate nights in a 4 x 2 design. The four experimental conditions under which they slept were: (1) no drug, (2) placebo, (3) mogadon (5mgs), and (4) seconal (100 mgs). Each subject spent 2 nights under each condition and during every alternate 24-hour period, they were off-duty and free to sleep as they pleased. Continuous EEG recordings were made on each "experimental" night and subjective ratings of mood and quality of sleep were used to complement the behavioral measures. Under both drug conditions there were changes in the EEG together with a slight decrement in vigilance performance in the later (1100-1500) runs of the day and an improvement in the rated quality of sleep.

10. Alluisi E. A. (1967). Methodology in the use of synthetic tasks to assess complex performance. Human Factors, 9, 375-384.

The application of synthetic tasks to the assessment of complex performance is discussed in relation to the trade-offs involved in achieving adequate levels of face validity and in specifying the exact changes in psychological functions that may result from particular environmental manipulations. It is argued that the multiple-task performance battery approach can provide levels of face validity adequate to maintain the motivation of subjects while at the same time permitting the identification of changes in specific performance functions. The characteristics of this approach are discussed in relation to a program of research on the effects of confinement and demanding work-rest schedules on crew performance.

11. Alluisi E. A. (1969). Research in performance assessment and enhancement. (PRL Report No. ITR-69-12). Louisville, KY: University of Louisville, Performance Research Laboratory.

The organization and research program of the University of Louisville's Performance Research Laboratory for "Studies of Performance Assessment and Enhancement", are described. Research is concentrated in the area of sustained performance, or work behavior, as affected by factors such as endurance and work-rest scheduling, illness and organismic variables, forced sleep and sleep-wakefulness cycling, and other environmental, task, and situational stresses.

Results of prior studies are presented and interpreted with regard to (a) the equivalence of different durations of work, depending on the constraints and demands of the "non-work" or "rest" periods of the work-rest schedule, (b) the effects on performance of the underlying psychophysiological diurnal rhythms and certain characteristcs of such rhythms, (c) the combined effects of sleep loss and demanding work-rest schedules, and (d) the effects of infectious diseases on work behavior.

12. Alluisi E. A. (1969). Sustained performance. In E. A. Bilodeau (Ed.), Principles of skill acquisition (pp. 59-101). New York: Academic Press.

The author presents the philosophy, techniques, and data of a program of research on the assessment of sustained performance on man's work behavior. The methodology developed employed a synthetic work situation in which it is possible to measure and evaluate the performance of subjects or operators who are required to work at time-shared tasks presented with a multiple-task performance (MTP) battery. The tasks themselves were selected to measure certain behavioral functions that man is called upon to perform in a variety of work situations in

complex man-machine systems. Specific research studies dealt with confinement in a volumetrically restrictive environment, sustained performance, work-rest scheduling, and diurnal rhythms in man, and with the behavioral effects of infectious diseases.

The general conclusions of the experimentation are: (1) Crews consisting of as many as 10 men can be confined in a space as small as 1100 cu.ft. for as long as 30 days or more without observable detriment. (2) Men apparently can follow a work-rest schedule of 4 hours on-duty and 4 hours off for very long periods without damage to their performance. (3) For shorter periods of 2 or possibly 4 weeks, selected men can follow a more demanding 4-2 work-rest schedule with reasonable maintenance of performance efficiency. (4) In following the more demanding schedule, man uses up his performance reserve and so is less able to meet the demands of emergency conditions such as those imposed by sleep loss. (5) The diurnal rhythm which is evidencial in physiological measures may also be evidenced in the performance, depending on the information given to, and the motivation of the subjects, and on the total workload. (6) Even where motivation is sufficiently high, diurnal cycling of performance may be demonstrated when the operator is over-loaded or stressed. (7) The average performance efficiency of a crew of men will drop between 25 and 33% during a period of illness with a febrile disease such as tolaremia. (8) During such an illness, the average drop in performance efficiency is between about 6 and 8% per 1 degree F rise in rectal temperature; but (9) individual differences will be very great and may be expected to range from essentially no decrement to one of 20% per degree.

In short, the synthetic-work methodology and its Multiple Task Performance (MTP) batteries appear to yield measures of sustained performance that are sensitive to the manipulation of both obvious and subtle experimental variables. They have provided a means for the conduct of experimental research on sustained performance or work behavior, and the data collected have led to inferences and conclusions like those listed in the preceding paragraph.

13. Alluisi E. A., & Chiles W. D. (1967). Sustained performance, work-rest scheduling and diurnal rhythms in man. Acta Psychologica, 27, 436-442. (DTIC No. AD 644-152).

This paper summarizes a 10-year program of research that dealt with sustained performance, work-rest scheduling, and diurnal rhythms in man. The general conclusions reached are: (1) man can probably follow an alternating 4 hours of work-4 hours of rest schedule for very long periods without detriment to his performance; (2) for shorter periods of 2 or possibly 4 weeks, selected men can follow a more demanding 4 hours of

work-2 hours of rest schedule with reasonable maintenance of performance efficiency; (3) in following the more demanding schedule, man uses up his performance reserve and so is less able to meet the demands of emergency conditions such as those imposed by sleep loss; (4) the diurnal rhythm which is evidenced in physiological measures may also be evidenced in the performance depending on the information given to and the motivation of the subjects, and depending also on the total workload; even where motivation is sufficiently high, the cycling may be demonstrated when the operator is overloaded; and (5) the methodology employed yielded measures that are sensitive to the manipulation of both obvious and subtle experimental variables.

14. Alluisi E. A., Chiles W. D., & Hall T. J. (1964). Combined effects of sleep loss and demanding work-rest schedules on crew performance. (USAF AMRL Report No. TDR-64-63). Wright-Patterson Air Force Base, OH: US Air Force Aerospace Medical Research Laboratories.

Four 12-day confinement studies are reported. In two of these studies, subjects in two 5-man crews worked alternating shifts on a schedule of 4-hours on duty and 4-hours off for the entire 12-day confinement period. In the other two studies, six USAF Pilots were confined for 12 days while following a schedule of 4-hours on duty and 2-hours off. The groups in each study were confined to a simulated advanced-system crew compartment; while on duty the operators were tested with a battery of six performance tasks, two of which required interactions among crewmembers in the form of exchanges of information, cooperation, and temporal coordination. During the middle two days of the 12-day confinement period (on days 6 & 7) the crews following the 4-4 work-rest schedule were assigned extra work that resulted in each man remaining awake for a 44-hour period; on the same days, the crews following the 4-2 schedule were assigned extra work that resulted in each man remaining awake for a 40-hour period.

Performance was generally inferior on the 4-2 schedule as compared to the 4-4 schedule and the stress of a period of sleep loss resulted in generally greater performance decrements on the 4-2 than on the 4-4 schedule. The 4-2 schedule is not recommended if emergency periods involving sleep loss can be expected and a high level of performance is a critical requirement.

15. Alluisi E. A., Chiles W. D., Hall T. J., & Hawkes G. R. (1963). Human group performance during confinement. (USAF AMRL Report No. TDR-63-87). Wright-Patterson Air Force Base, OH: US Air Force Aerospace Medical Research Laboratory.

Six Air Force Academy cadets were confined for 15 days in a simulated advanced-system crew compartment while following a schedule of 4-hours on duty and 2-hours off, and two 5-man crews of US Air Force pilots were confined for 30 days while alternating shifts on a schedule of 4-hours on duty and 4-hours off. While on duty the operators were tested with a battery of 6 performance tasks, 2 of which required interactions among crewmembers in the form of exchanges of information, cooperation, and temporal coordination. In addition, the data of the present studies were compared with those of two previous 15-day tests of two crews who worked the 4-2 schedule while being tested with a battery of 5 individual-performance tasks. The data suggest that with proper control of selection and motivational factors, crews can work effectively for periods of at least 2 weeks and probably longer using a schedule of 4-hours on duty and 2-hours off. Crews can work even more effectively for periods of at least a month and quite probably for 2 or 3 months using a schedule of 4-hours on duty and 4-hours off, and with this schedule less demanding controls of selection and motivational factors are required.

16. Alluisi, E.A., & Morgan,B.B. (1982). Temporal factors in human performance and productivity. In: E.A. Alluisi, & E.A. Fleishman (Eds.). Human performance and productivity, Volume 3: Stress and performance effectiveness. (pp 165-247). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

This survey review chapter covers empirical studies from the lab and the field on temporal factors in human performance and productivity; identifies those temporal factors that have major impact; specifies the effects of those factors on work efficiency, with the assessment of means whereby they might be appropriately manipulated or managed to optimize or at least enhance human performance and productivity; and identifies meaningful questions that warrant further research

The chapter covers such topics as the length of industrial work shifts, work days, work-weeks, scheduling and productivity; lab studies of work-rest cycles, circadian rhythms and work, work-rest schedules, the duration of work, sleep wakefulness cycles, the duration of sleep, continuous work and sleep loss and non-temporal factors.

17. Anderson D. B, & Chiou W. C. (1977). Physiological parameters associated with extended helicopter flight missions: An assessment of pupillographic data. (USAARL Report No. 77-21). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

Six Army aviators served as subjects in a study of various psychological and physiological parameters associated with an extended helicopter flight schedule lasting 12 hours per day for five days. This report presents the results of pupillographic data collected in the study as well as the problems encountered and the recommended solutions. It was shown that the wave-form characteristics of the pupillary reflex response to light were irregular. Furthermore, the blinking frequency increased and the pupillary amplitude varied as a function of loaded flight task. Results also revealed that the average pupillary diameter was smaller in the morning than in the evening. This report recommends the future use of pupillography in which an evaluation of pilot alertness is needed.

18. Angus R. C., & Heslegrave R. J. (1983). The effects of sleep loss and sustained mental work: Implications for command and control performance. In J. Ernsting (Ed.), Sustained intensive air operations: Physiological and performance aspects: Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338, pp. 11-1 to 11-21). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-986).

Technological advances permitting sustained military operations will increase the vulnerability of the human in battle. Studies have examined the simplest yet probably one of the more debilitating aspects of continuous operations, the effect of sleep loss. But, previous sleep deprivation studies may not provide valid estimates of the cognitive deficits that emerge due to sleep loss for tw reasons: first, most studies have measured performance only on an intermittent basis, and second, most studies have required continous sleep deprivation but have not required continuous work.

This study represents an attempt to address these limitations by requiring and measuring performance on a continuous basis. Subjects were required to perform continuous cognitive work in a command post during a simulated sustained battle. They assumed the role of operations duty officers and were required to handle message traffic during a 54-h period of wakefulness. Performance was evaluated by monitoring the subjects' message-processing ability and by other objective tests embedded in and interspersed around the messages. Data are presented to show that sleep loss and sustained mental work can have dramatic effects on cognitive functions, even during

the first night of sleep loss. The data also revealed that under this continuous cognitive workload, performance systematically declined.

After 18 hours, performance declined substantially and remained at this lower level for approximately another 24 hours. Performance then declined again to a level that would generally be viewed as unacceptable.

19. Angus R. G., & Heslegrave R. J. (1985). The effects of sleep loss on sustained cognitive performance, during command and control simulation. Behavior Research Methods, Instruments & Computers, 17, 1, 55-67.

Findings from previous studies of sleep loss may not provide valid estimates of cognitive deficits that could emerge during sustained high-intensive military operations for two reasons. First, most studies assessed subjects' capabilities only on an intermittent basis; and second, most studies required very little in terms of cognitive work during periods between test sessions. The research reported here addresses these limitations by requiring and measuring performance on a continuous basis in a computerized laboratory environment in which subjects assumed the role of command post duty officers. They were required to handle message traffic during long periods of wakefulness and their performance was evaluated by means of cognitive tests embedded in and interspersed around the messages.

The methodology is described and some findings are reported from a continuous 54-hr experiment showing greater decrements than previous research wherein subjects were not tested under such demanding conditions. The implications of these findings are discussed.

20. Aschoff J. (1978). Features of circadian rhythms relevant for the design of shift schedules. Ergonomics, 21(10), 739-754.

The first part of this paper reviews properties of circadian rhythms when free-running in constant conditions, or in situations where zeitgebers are insufficient for entrainment. The second part deals with the problems of entrainment by natural and artificial zeitgebers, with phase controlling effects of sleep and the timing of meals, and with the need to differentiate between entraining and masking effects. The third part discusses phase shifts of circadian rhythms, especially the dependence of the rate of re-entrainment, the direction of the shift, and the splitting of the circadian system into parts which are shifted in opposite directions (re-entrainment by partition). The relevance of these features of circadian rhythms for the design of shift-work schedules is discussed.

21. Aschoff J. (1981). Circadian Rhythm: Interference with and dependence on work-rest schedules. In L.C. Johnson, D.I. Tepas, W.P. Colquhoun & M.J. Colligan (Eds.), The twenty-four hour workday: proceedings of a symposium on variations in work-sleep schedules. (DHHS-NIOSH Report No. 81-127) (pp. 13-50). Cincinnati, OH: US Department of Health and Human Services, National Institute for Occupational Safety and Health.

A review article. Despite the multiplicity of its constituents, the circadian system often behaves like one unit which is characterized by the durability of its oscillations and its internal temporal order. This order is maintained by mutual coupling between the various components and, in the case of entrainment, by the signals from the zeitgebers. As a consequence, freerunning and entrained systems differ in the character of their internal order and in the stability of internal phase-relationships. The persistence of internally synchronized (free-running) rhythms under adverse conditions and the slow courses of re-entrainment after shifts indicate the rigidity of the system and its inertia.

There are, on the other hand, conditions under which the system, due to a loss of coupling between its constituents, is split into components that either can become desynchronized or react differentially to conflicting zeitgebers. In addition to this lability, there is a plasticity, predominately demonstrated by masking effects on the overt ryhthms. In the interplay between all these factors, the rhythm of sleep and wakefulness (of rest and activity) holds a specific place. Although itself a part of the system, and hence determined by it in some of its characteristics, the sleep-wake cycle exerts masking as well as phase controlling effects similar to those of zeitgebers. The analysis of this bi-directional interaction between the sleep-wake cycle and other components of the circadian system is presently one of the major tasks in this field of research.

22. Army Medical Research Lab. (1943). Crew fatigue research. (AMRL Report No. 3671H1). Fort Knox, KY: US Army Medical Research Lab. (DTIC No. AD 655-575).

From the point of view of driver fatigue, the Bendix Power Control tank, No. 908, is better than the standard M4A2 medium tank. The work output of the driver operating the standard medium tank M4A2 was 50% greater than when driving the Bendix tank No. 908. Driver fatigue in the Bendix 908 was not excessive. The fatigue resulting from driving the standard tank, if it could be run over such terrain for many hours without mechanical failure, would be excessive. On short runs of from 3 to 6 hours the driver of the standard tank showed higher pulse rates, had more symptoms of fatigue, and felt more tired than was the case when driving tank No. 908.

23. Atkinson D. W., Borland R. G., & Nicholson A. N. (1968). A study of the sleep rhythms in a double crew, five day continuous duty operation. (FPRC Report No. 1282). Farnborough, England: Flying Personnel Research Committee, Air Force Department, Ministry of Defence. (DTIC No. 859-428).

The sleep rhythms of aircrew, during a double crew continuous duty operation of approximately 110 hours duration, were studied in a Belfast heavy transport aircraft of the Royal Air Force. The study relates the subjective feelings of fatigue of the aircrew members to their sleep patterns and indicates possible patterns for duty during future flights of this duration. Also included is a list of recommendations for minimizing sleep disruption during long-haul transport operations.

24. Atkinson D. W., Borland R. G., & Nicholson A. N. (1970). Double crew continuous flying operations: A study of aircrew sleep patterns. Aerospace Medicine, 41, 1121-1126.

To increase the effectiveness of a strategic transport force in the absence of positioned crews, double crew continuous flying operations were studied. In such continuous flying operations, additional crews sleep aboard the aircraft instead of sleeping at route stations. The success of such operations depends to a large extent on the crew which operates during the period in which they are normally accustomed to sleep. Such missions may lead to sleep difficulties and it is concluded from two missions operated by the Royal Air Force Air Support Command that the optimum duration is 48 hours. Beyond this period, serious sleep disturbances appear. In the case of a fast strategic transport aircraft, this provides a worldwide capability, and during this time length the aircraft can circumnavigate the world.

25. Aviation Human Engineering Research Team. (1977). Survey report of the sleep time on the Moscow route (Mosukuwa sen sumin jikan chosa hoboku). Aviation and Space Laboratory, Tokyo, Japan. (NASA Report No. TT F-17-530, Translation, October 1976), Washington, DC: National Aeronautics and Space Administration Scientific Translation Service.

A study was conducted over three months on 23 subjects concerning changes in sleep patterns and sleep amounts which develop as a consequence of the time differential and the long work periods on the Tokyo to Moscow route. The results were as follows:

1) In both the three- and five-day patterns, an amount of sleep equivalent to one night's sleep was lost from

the departure on the Moscow route to the return to Tokyo. In both cases, that developed during the eastward flight to Tokyo from Moscow on the final part of the duty, and it was quite difficult to adjust to this insufficiency during lay-over before the return flight.
2) The amount of insufficicncy increased after Moscow departure and reached a peak about six hours into the flight. The amount was eight to ten hours. There was no significant difference in the cumulative amount of insufficiency, but the divergence from the activity time was greater in the five-day pattern and periods of insufficiency occurred periodically at four occasions so that the degree of fatigue was greater.
3) Based on their life styles in Tokyo, the participants were classified into a standard group whose members had regular hours of activity and an adaptable group whose members did not conform to standard hours for activities. The standard group had more hours of sleep on the average. While the adaptable group had fewer average hours of sleep, the effect was less if the hours of activity on Tokyo time were disrupted.

The characteristics of changes in the amounts of sleep and the sleep patterns which develop due to work on a long distance route were listed, but the survey itself had many imperfections.

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26. Baird, J.A. & Nicholson, A.N. (1983). Human factors of air operations in the South Atlantic campaign. In: J. Ernsting (Ed.), Sustained intensive air operations: Physiological and performance aspects, Proceedings of the NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO AGARD CP-338, pp 28-1 - 28-4). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P00 994).

During the British involvement in the Falkland Islands in April 1982, aircraft operated off of ships in the South Atlantic and from Ascension Island midway between the United Kingdom and the Falklands. Flights of up to 6,800 miles (11,000 km) posed operational and logistical difficulties and considerable problems for the aircrew.

From the earliest phase of the operation the medical staffs at the Headquarters of the Royal Air Force Strike Command and at the Royal Air Force Institute of Aviation Medicine gave advice on human factors for the aircrew and ground personnel including considerations of the aircraft role, crew tasks in flight, duration and frequency of flights, number of sorties per detachment and length of detachment, problems of supervision and management, changes in work associated with unusual patterns of rest, rest facilities and other aspects such as feeding, bowel and urinary functions, morale and motivation.

The operation posed two particular problems: sorties of very long duration and intensive rates of work. A balance between flight safety and acceptable operational risk during war had to be achieved. Hypnotics were used from the early stages of the campaign. Aircrew took 20 mg of temazepam to get sleep at various times of the day and experienced good sleep without side or residual effects. They found they could fly 6 hours after taking temazepam some eight hours before flight time without any ill effect. Hundreds of aircrew members used this hypnotic successfully during the campaign.

27. Banderet L. E., & Stokes J. W. (1980). Simulated, sustained combat operations in the field artillery fire direction center (FDC): A model for evaluating biomedical indices. (USARIEM Report No. T 9-80). Natick, MA: US Army Research Institute of Environmental Medicine.

Military biomedical scientists must quanfify how biological and behavioral phenomena influence operational capability and military effectiveness. To this end, four 82d Airborne Division FDC teams were tested in simulated, sustained combat operations. Role players interacted from scripts describing mission demands matched across time. Biomedical data were also obtained. All teams performed intense workload operations, without shifts. Teams 1 & 4 anticipated a single 86 h challenge; they discontinued after 48 & 45 h. Teams 2 & 3 experienced two 38 h challenges separated by 34 h rest; however, a Team 3 member withdrew after 6 h (second challenge).

Accuracy for on-call missions against preplanned targets suffered in Teams 1 & 4. After 36 h, much preplanned target processing was never completed, not even for priority targets. In the second challenges, Teams 2 & 3 showed reduced preplanning efficiency after 24-36 h. Verbal communication units decreased during lulls, larger task-related ratios preceded performance deteriorations. The ratios of Teams 1 & 4 increased until 24-30 h. Later, preplanning activities deteriorated markedly and communication ratios decreased, suggesting conservation and/or unwillingness (inability) of team members to sustain performance. Thus, simulation of an actual Army team task provides a framework for validating biomedical indices. The impact of biomedical, behavioral, biochemical, and social changes can be demonstrated by relating them to FDC operational indices. Research findings from this program are applicable to military users, planners, and modelers.

28. Banderet L. E., Stokes J. W., Francesconi R., & Kowal D. (1980). Simulated, sustained-combat operations in the field artillery fire direction center (FDC): A model for evaluating biomedical indices. (USARIEM Report). Natick, MA: US Army Research Institute of Environmental Medicine. (DTIC No. AD A090-362/5).

In evaluating conditions which affect human performance, the scientific literature indicates the importance of task, personnel, and organizational variables. These include: task complexity, feedback, pacing, level of training, intrinsic task interest, experience, motivation, and social factors. Such variables are considered critical determinants of performance capability under a variety of conditions. In the military community, concerns are often expressed as to the generality

and predictive validity of past studies which have not included variables inherent in many military tasks.

To address these issues and provide a framework for communicating research results to the military community, the Field Artillery fire direction center (FDC) was selected as a "model" team for study. It was postulated that these issues could be addressed in a laboratory simulation which would use actual Army artillery teams performing their normal functions. This would permit control and replication of environmental and situational conditions and measurement and correlation of mission effectiveness, behavior and biological processes. This report documents the design of such a simulation setting for sustained military operation studies in the laboratory.

29. Banderet, L.E., Stokes, J.W., Francesconi, R., Kowal, D.M., & Naitoh, P. (1981). Artillery teams in simulated sustained combat: Performance and other measures. In: L.J. Johnson, D.I. Tepas, W.P. Colquhoun & M.J. Colligan (Eds.), The twenty-four workday: Proceedings of a symposium on variations in work-sleep schedules. (DHHS NIOSH Report 81-127 pp 581-604) Cincinnati, OH: Department of Health and Human Services, National Insitute for Occupational Safety and Health.

Test participants worked in a five man artillery fire direction center (FDC) in a laboratory simulated tactical battle scenario on 1:50,000 scale maps and followed current doctrine for light infantry with armored cavalry advancing against a well-equipped screening force. To permit performance assessment over time, the scenario was organized into equivalent 6 hr epochs of mission demands. In each 6 h, events of differing importance complexity, and urgency required different individual and team responses, and recurred with sufficient frequency to permit event pooling for analysis of performance data (accuracy and timeliness measures, audio tapes, log books, plotting sheets etc.).

Two designs were used. One had a single 86 hour operational challenge; whereas the second design had two 38 hr challenges separated by a 34 hr rest and relaxation interval.

Two teams completed the two 38-hr challenge design without gross perfromance deterioration. However, a 3rd team, exercised the right to withdraw from the continuous operations design after 48 hours. It had made several errors in the last 8 hrs which "endangered" friendly troops and the troops were extremely fatigued.

For all teams, accuracy of firing data for unplanned missions was generally well maintained, even until termination. In contrast, accuracy of firing data for

preplanned targets fired upon during on-call missions was less for all teams and deteriorated progressively over time for two teams. Timeliness for missions suffered in two of the three teams.

30. Banks, J.H., Sternberg, J.J., Farrell, J.P., Debrow, C.H. & Dalhamer, W.A. (1970). Effects of continuous military operations on selected military tasks. (BESRL Report No. 1166). Arlington, VA: US Army Behavioral and Systems Research Laboratory.

This report covers a series of 8-10 studies over a 10 year period on the effects of sustained operations (36 hours) on the abilitiy of Vietnam returnee infantrymen to detect targets using various surveillance, target acquisition and night operations devices. The tests were conducted at Ft. Hunter Ligget, CA. The soldiers were required to attack hills under simulated fire, throw hand grenades, go on extended marches while being attacked by an agressor force and to do other soldier tasks. The dependent measures were designed to examine the gradual fatigue effects on the ability to detect targets using passive night vision devices such as the night observation device (NOD), a rifle mounted starlight scope, a tri-pod mounted crew served night vision device for use with the machine gun and early versions of the night vision goggles (NVG).

A special analog-digital computer system was devised to control and record target locationss and to determine target hit scores; later it was also used for data analysis.

31. Barreca N. E. (1972). Flying fatigue. US Army Aviation Digest, 23, 14-16.

This article discusses problems and preventive measures for military aircrew fatigue. Hypoxia, decompression sickness, acceleration, noise, and vibration are identified as environmental fatigue-producing stressors which must be recognized and controlled if skill fatigue is to be reduced. Other psychological and emotional stresses are also described. Symptoms of potentially dangerous fatigue such as acceptance of lower performance standards, loss of control smoothness, and neglect for peripheral tasks are described along with verbal responses a fatigued crewmember might exhibit. Specific advice is offered to aircrew commanders concerning fatigue prevention and implementation of provisions of the US Army Regulation 95-1 governing flight time limits.

32. Beare A. N., & Bondi K. R. (1981). Work and rest on nuclear submarines. Ergonomics, 24(8), 593-610.

Hours of work and sleep were recorded in daily activity logs by 46 enlisted men on two fleet ballistic missile submarines during routine patrols. Total working time (watch standing, non-watch work, and study) averaged 12 hours a day. Daily sleep time averaged 8.4 hours a day on one ship and 7.6 on the other. Sleep was mildly fragmented in that the men averaged 1.3 sleep episodes, of somewhat less than 6 hours duration, in 24 hours. Thirty of the men were standing watch on a 6-hours on-12-h off rotation which effectively imposed an 18-h cycle on their activities. The 6-on-12-off watch schedule appeared to result in less sleep fragmentation than the traditional 4-on-8-off schedule employed on other Naval ships.

Questions in the logs were used to assess subjective sleep quality and sleepiness. Sleep quality on patrol was not as good as in a post-patrol period, but the difference between on- and off-patrol sleep quality was small.

33. Beck R. A. (1964). Jet crew fatigue. Combat Crew, 15, 4-7.

This article discusses medical aspects that affect jet aircrew members in the performance of their duties. Two types of jet crew fatigue are identified: acute fatigue, which results from normal work and disappears with normal rest, and chronic fatigue, which is a cumulative phenomenon resulting when physical and inertial recuperation between flights is incomplete. Jet crew fatigue is compared with piston engine aircrew fatigue with special emphasis given to the Juin Report. Diurnal rhythms and time zone shift are also identified as factors contributing to jet crew fatigue. The results of Air Force Operation Headstart, an extended flight study of B-52 bomber crews conducted in 1958, are briefly summarized.

34. Behar I., Kimball K. A., & Anderson D. A. (1975). Dynamic visual acuity in fatigued pilots. (USAARL Report No. 76-24). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

Six rotary wing aviators were subjects in a continuous operation regimen involving some 12 hours of flying and 3.5 hours sleep daily for five days. Estimates of performance on a dynamic visual acuity (DVA) task were obtained several times each day during the study using target velocities of 25 degrees and 40 degrees/sec. DVA performance varied significantly during the fatigue regimen when measurements were made with target velocities of 40 degrees/sec; with lower velocity targets, differences in DVA scores were not significant. This

indicates the need to tax the oculomotor system to demonstrate fatigue effects. Fatigue effects were partially obscured by practice effects which are considerable in the DVA task. DVA scores correlated only modestly with subjective estimates of fatigue intensity and flying performance, and instructor pilot ratings of performance; but the cluster, of correlations provided a consistent picture.

35. Benson A. J., (Ed.). (1970). Rest and activity cycles for the maintenance of efficiency of personnel concerned with military flight operations: Proceedings of the NATO advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Oslo, Norway, May 1970. (NATO/AGARD Report No. CP-74-70). London: Technical Editing and Reproduction LTD.

This volume contains the text, discussion and technical evaluation of ten papers presented at the meeting convened in response to a request from the Military Committee of NATO for advice on the influence of work and rest schedules on the operational efficiency of personnel concerned with flight operations. Papers are presented in three main categories: (a) Laboratory investigations of normal and abnormal work-rest schedules, (b) inflight studies of aircrew operating long-haul transports, and (c) duty cycles in air traffic control tasks.

36. Berliner D. S. (1975). Joint committee on aviation pathology: VIII Crew rest and nap-of-the-earth flying. Aviation, Space, and Environmental Medicine, 46, 1267-1270.

Nap-of-the-earth flying was conceived by the US Army to evade enemy detection of rotary wing aircraft, requiring the stressful technique of aircraft movement only inches above the ground terrain. The 101st Airborne Division (Airmobile), Fort Campbell, Kentucky, tested the nap-of-the-earth (NOE) concept from June 1973 to June 1974, flying 3267 hours in NOE training. Four aircraft incidents occurred during this training period, with three of these taking place prior to March 1974. At that point, after over 59% of the total hours had been flown, NOE pilot training was curtailed from 8 hours per day to 4 hours per day. Objective and subjective data infer that pilot (crew) rest and the length of the flying day are important factors in the safety of NOE flying.

37. Bodanowitz M. (1973). Change of circadian rhythm of psychomotor performance after transmeridian flights. (DLR Report No. FB 73-52). Bonn-Bad Godesberg, Germany: Deutsche Forschungs-und Versuchsanstalt fur Luft-und Raumfahrt.

Psychomotor performance was studied in 8 students in 3-hour intervals during periods of 24 hours before and after

flights between Germany and the USA. Two 24-hour preflight periods revealed the basic normal daily rhythm of psychomotor performance. Effects of a 6-hour time shift were evaluated by determining the psychomotor performance on day 1, 3, 5 and 8 following the flights in each direction. Desynchronisation with the local time was observed after flights in both directions. The changes were more pronounced and longer lasting after the west-east flight. The resynchronisation time amounted to 5 days after the westward travel and to 8 days after the eastward direction.

38. Boissin J. P., & Abbas L. (1975). Variations of certain ocular system parameters as a function of fatigue resulting from long-haul flights. (Variations de certain parametres du systeme oculaire en fonction de la fatigue lors des vols long-courriers). Revue de Medecine Aeronautique et Spatiale, 14, 65-67. (In French). (NASA Report No. A77-32352).

Ocular tonus, types of phoria, ophthalmic arterial tension, punctum proximum of convergence and of accomodation, amplitude of fusion in convergence and divergence, and normal nyctohemeral rhythms (response to jet lag) were studied in crewmembers experiencing two ten-hour nonstop flights, with 9 hours jet lag in one direction, before and after rest periods. The time involved was found too short to affect ocular tonus. Ophthalmic arterial tension was not affected by flight fatigue per se, unless accompanied by a heavy workload or added stress. Variations in the punctum proximum for convergence were observed in some individuals, with some variations in the punctum proximum for accommodation in the case of presbyopic subjects.

39. Bond J. S. (1978). Crew rest in reserve/guard components. US Army Aviation Digest, 24, 38-39.

Pilot fatigue causes are related to the typical reserve/guard drill weekend. Special reserve/guard problems are discussed. A sample crew rest questionnaire, developed specifically for reserve and guard units, is presented.

40. Bonnet M. B., & Webb W. B. (1978). The effect of repetition of relevant and irrelevant tasks over day and night work periods. Ergonomics, 21(12), 999-1005.

The effects of repetition on the Wilkinson Vigilance Task and an unobtrusive performance measure (crossword completion) were examined in 18 subjects over two 8 h work periods. Vigilance trials alternated with breaks in 25 min segments across a work period from 0900 to 1700 h and a period from 2400 to 0800 h. Performance decrements were seen in hit rate and on the irrelevant task measure across the night session, and in

hit rate across the day session. Decrements were greater at night than during the day on both measures. The number of attempts on the vigilance task decreased across trials similarly in both testing sessions. It was concluded that specific task repetition results in performance decrements, even when circadian incremental effects would be predicted, and that the placement of such task repetition at night magnifies those decrements and extends them to intrinscially as well as extrinsically motivated tasks.

41. Bonnet M. H. (1980). Sleep, performance and mood after the energy-expenditure equivalent of 40 hours of sleep deprivation. Psychophysiology, 17(1) and (NHRC Report No. 79-7). San Diego, CA: Naval Health Research Center.

Twelve Marine subjects marched approximately 20 miles to expend as much energy in one 16-hr day as is expended during 40 hrs of relatively inactive sleep deprivation. At the end of the march, performance on addition, vigilance, choice reaction time, tapping, short-term memory, symbol substitution, and three mood scales was decremented significantly. Those decrements closely approximated those reported in the literature following 40 hrs of sleep deprivation. However, recovery sleep stages and arousal thresholds were essentially unchanged as compared to baseline and were significantly different from those predicted after 40 hrs of sleep loss. It was concluded that while changes in performance were probably linked to total energy consumption, the commonly measured sleep variables were not.

42. Borland R. G., & Rogers A. S. (1983). Workload of personnel engaged in air defence. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects: Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338, pp. 27-1 to 27-6). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002 993).

Workload has been defined in many ways and the methods that have been employed to quantify workload are a legend. In the past it has been common practice to limit the "system" to the local environment or crew station and to consider the engineering, physiological and psychological factors affecting the operator. Little attention has been given to studying the workload imposed by the daily pattern of work and rest. As Selye (1974) points out, stress is a reasonably normal component in every day life and can be adaptive, but, cumulative stress becomes mal-adaptive and ultimately then stress becomes distress.

In Spring of 1979 a preliminary study was carried out on

the work of two air defense squadrons. Self-reporting diaries covering a 60 day period were issued to all aircrew. A more detailed investigation included rest and workload study of ground support and ground environment personnel in 1980 and covered a period of time of a joint NATO exercise, "Elder Forest". 514 diaries were issued for a 42-day period. The returns were analyzed for the distribution of different types of duty within work periods.

43. Brictson C. A. (1975). Prediction of carrier aviator performance during sustained operations at sea: Summary paper. Presented at the American Psychological Convention. Chicago, IL. La Jolla, CA: Dunlap and Associates, Inc.

The research summarized here stems from an initial interest by the Bureau of Medicine and Surgery in defining and describing the influence of environmentally related variables on overall aviation performance effectiveness. The specific environment studied was that of long term combat deployment.

44. Brown I. D. (1965). A comparison of two subsidiary tasks used to measure fatigue in car drivers. Ergonomics, 8, 467-473.

Car driving has been studied by combining it with a subsidiary task, performance on which is negatively correlated with the perceptual load imposed by changing conditions of traffic. The present experiment compares a subsidiary task which required almost continuous attention to an auditory display, and which involved memory spans of only 3 sec, with an alternative task which did not require continuous attention, but which involved memory spans of up to 55 sec. The former was found to have some advantages. This comparison was combined with a study of men engaged in 8-hour spells of car driving. Some explanations are offered for the finding that performance on the subsidiary tasks was better at the end of the work-spell than at the beginning.

45. Brown I. D. (1967). Decrements in skill observed after seven hours of car driving. (Report No. APU-643-67). Cambridge, England: Medical Research Council. (DTIC No. AD 696-349).

The performance of car drivers was assessed in city traffic at 9 A.M. and 4-15 P.M. on two days. In one group they also drove alone between the test; in another group they did laboratory work. Six experienced drivers judged performance on the P.M. test to be worse when driving had continued. The decrement was related to perceptual skills, courtesy shown towards other road users, and motor skills.

46. Brown I. D. (1967). Measurement of control skills, vigilance, on a subsidiary task during 12-hours of car driving. Ergonomics, 10(6), 665-673.

Eight subjects were given short driving tests at 0700, 1000, 1300, 1400, 1700 and 2000 hours on 2 days: (1) under experimental conditions of continuous driving and (2) under control conditions in which they carried on with their normal work between tests. Car control skills and performance on a subsidiary task of time-interval production were measured on a 2.2 mile test circuit in city traffic. Pulse rate and oral temperature were also recorded. Vigilance was measured during main-road driving on the experimental day by scoring time taken to respond to a light signal. Vigilance improved significantly during the spell of prolonged driving. Time-interval production was more variable under experimental conditions than under control, but this difference was independent of the duration of the driving period. Differences in car-control skills between conditions were slight and statistically unreliable.

These results support previous findings that a virtually continuous 12 hour period of driving during the normal working day need not affect either perceptual or motor skills adversely. The apparent discrepancy between present findings, (that performance on the subsidiary task was worse on the day of prolonged driving), and previous findings, (that it tended to be better), is discussed in relation to the general problem of measuring performance by the dual-task method.

47. Brown W. K., Rogge J. D., Meyer J. F., Buckley C. J., & Brown C. A. (1969). Aeromedical aspects of the first nonstop transatlantic helicopter flight: II. Heart rate and ECG changes. Aerospace Medicine, 40, 714-717.

Electrocardiographic data were recorded continuously on three crewmembers during a 30-hour transatlantic flight in an H-3 helicopter. Heart rate changes during the flight were compared with control heart rates during routine daily activities. Changes in heart rates during flight indicated that there were significant periods of rest. The marked increases in heart rate associated with obvious stressful events such as air refueling indicate that heart rate may be a good index of acute stress. However, the lack of change in mean heart rate over control values in two of the three crewmembers indicate that either the stress was less than expected or heart rate does not adequately reflect prolonged stress.

48. Bryden G., & Holdstock T. L. (1973). Effect of night duty on sleep patterns of nurses. Psychophysiology, 10(1), 36-42.

The diurnal sleep patterns of female nurses working night duty were compared to their nocturnal sleep patterns while they were working regular hours during the day. Continuous EEG, EOG, and EMG recordings were made at the end of 2 month periods of night and day duty respectively. Day and night sleep differed with respect to both duration and pattern. Despite an earlier onset, the major sleep period was shorter during the day than the night and seemed to be more interrupted later in the session. This finding is in keeping with the increased amount of Stage 1 and decreased amount of slow wave sleep during the day than the night.

Although no differences were evident with respect to overall percent REM, differences in the distribution of REM did occur. REM sleep occurred sooner during day than night sleep and there was more of it during the first part of day sleep. Thus night duty seemed to affect the pattern of sleep stage distribution as well as the absolute amount of, not only total sleep, but also some sleep stages, such as Stage SS (slow wave sleep). It is an open question how the naps of extended duration taken while on night duty influence the pattern of sleep during the day.

49. Buck L. (1975). Sleep loss effects on movement time. Ergonomics, 18(4), 415-425.

Subjects were tested on a subject-paced step-tracking task three times every four hours under two regimes: one in which they slept for 6.5 hours at night and one in which they remained awake. 12 subjects were tested for two days under each condition, and 8 subjects for three days. Reaction times for correct responses increased following sleep loss to an extent inversely related to signal probability. Movement times increased following sleep loss to a much greater extent. It is concluded that movement time is a more sensitive index of performance deterioration due to sleep loss and that movement time and reaction time represent separate processes.

50. Buck, L. (1976). Psychomotor test performance and sleep patterns of aircrew flying transmeridional routes. Aviation, Space and Environmental Medicine, 47, 979-986.

Pilots and flight attendants flying scheduled services between Vancouver and Tokyo and between Toronto and Rome were tested on a tracking task before and after flights in each direction. Flights were included in schedules involving both 24-hours and 7-day layovers at the overseas station. During these periods, they recorded their sleep patterns. The data

showed that, following flight, subjects made an immediate attempt to adapt their behavior to local time and the changes in their performance scores could be interpreted on that basis. It was concluded that behavioral circadian rhythms adapt rapidly to a new time zone.

51. Buck L., Gibbs C. B., & Leonardo R. (1969). Sleep deprivation effects on responses to signals of unequal probability in an artifically charged environment. (Canadian NRC Report No. DME-ML-4). Ottawa, Canada: National Research Council of Canada, Division of Mechanical Engineering. (DTIC No. AD 703-197).

Young male subjects made repeated runs on a step-tracking task over a period of 48 hours during which they were deprived of sleep. Successive runs showed a reaction time (but not error rate) increase that was inversely related to signal probability, and a movement time increase that was related to distance travelled. Both effects were more evident on machine-paced than subject-paced tracking. There was no evidence that performance deterioration could be modified by the use of a patented anti-fatigue device.

52. Buckley C. J., & Hartman B. O. (1961). Aeromedical aspects of the first nonstop transatlantic helicopter flight: I. General mission overview and subjective fatigue analyses. Aerospace Medicine, 40, 710-713.

Effects of stress and fatigue on aircrew members participating in the first nonstop transatlantic helicopter flight were examined. A general mission narrative and observations of the flight surgeon crewmember are presented together with results of subjective fatigue rating and sleep pattern survey studies, continuous electrocardiographic recordings, and the analyses, of altered excretion patterns of urinary constituents commonly affected by stress and/or fatigue. Results indicate that satisfactory aircrew performance can be maintained when helicopter crewmembers are exposed to the levels of stress and fatigue which were encountered on this record duration helicopter flight, but certain deficiencies in life support/crew comfort items available to the helicopter crewmember exist when this type aircraft is employed for missions in excess of six or eight hours duration.

53. Bugge, J.F., Opstad, P.K., & Magnus, P.M. (1979). Changes in the circadian rhythm of performance and mood in healthy young men exposed to prolonged, heavy physical work, sleep deprivation, and caloric deficit. <u>Aviation, Space Environmental Medicine</u>, 50 (7) 663-668.

Eighteen young men participated in a ranger training course in June 1978 with more than 100 hours of continuous activities, almost without sleep. The subjects used about 10,000 kcal/d and their food intake gave only about 1,600 kcal/d. Changes from circadian rhythm in performance and mood were studied once in the week before the course, on the first and last day of the course, and once in the week after the course. The subjects were tested at 4-h intervals.

Significant and substantial impairment were observed in all tests, as well as in mood during the course (more pronounced on the last day). The impairment was mainly in reduced capacity, although there were minor increases in errors. The oscillations in circadian rhythm during baseline and recovery were small (+/- 10% of the 24h mean), with a tendency to have low values in the early morning. The oscillation increased during the course to 20-40% of the 24h mean; the tendency was to increase the fluctuations of the natural circadian rhythm with a crest in the afternoon and a trough in the early morning. The profile of mood-state showed similar fluctuations and was highly correlated to performance. After 4 days of rest, there was complete restitution of performance and mood in our tests.

54. Burton R. R., Storm W. F., Johnson L. W., & Leverett S. D. (1977). Stress responses of pilots flying high performance aircraft during aerial combat manuevers. <u>Aviation, Space, and Environmental Medicine</u>, <u>48</u>, 301-307.

In aerial combat maneuvers (ACMs), at Luke AFB, Arizona, 8 fighter pilots flew their two F-15 aircraft against 9 pilots in three F-106 aircraft. A total of 9 flights, consisting of 23 ACMs, were accomplished in 5 successive days. The degrees of fatigue, stress, and sympathetic activity were quantified using both subjective analyses and the biochemical constituents in the urine of the pilots of the F-15 or F-106. Biochemical indicators, reported per 100mg creatinine, included: epinephrine, norepinephine, 17-OHCS, urea, inorganic phosphate, sodium, potassium, and sodium/potassium ratio.

The F-106 pilots exerted more relative effort than did the F-15 pilots--effort which appeared to be associated with high-G experience. Both groups of pilots were equally fatigued following ACMs; however, only the fatigue of the F-106 pilots was directly correlated with the length of the ACM.

Sympathetic and stress responses during the ACM - similar for both groups of pilots - showed postflight increases of 54% in epinephrine, 19% in norepinephrine, and 20% in 17-OHCS over preflight values, thus suggesting a moderate stress response. Resting levels of these same indicators, (for days the pilots did not fly and for pre-ACM values) were similar but higher than control values previously reported for other stressful activities. By late afternoon, postflight values for these indicators had returned to near-preflight levels.

55. Byrne D. (1964). What's being done about crew fatigue? American Aviation, 27, 65-66.

This article outlines plans for upcoming research into jet flights across time zones and fatigue. Plans for an FAA Civil Aeromedical Research Institute study of jet crew fatigue on flights from Oklahoma City, Oklahoma, to Frankfurt, Germany, and from Oklahoma City to Tokyo are discussed. Fatigue is also identified as a social problem among jet crews which results in increased irritability and decreased libido. The author predicts that new crew scheduling regulations will be instituted either by FAA regulation or by the airlines themselves as a result of fatigue experiments.

C

56. Caille E. J. P., Quideau A. M. C., Girard J. F. J., Grubar J. C., & Monteil A. C. (1972). Loss of sleep and combat efficiency: Effects of the work/rest cycle. In W. P. Colquhoun (Ed.), Aspects of Human Efficiency. pp. 177-194. London, England: The English Universities Press Ltd.

Military duties are liable to impose severe stresses on the normal biorhythm of the 8-hours rest - 8-hours work - 8-hours rest schedule. The aims of this study were: to define the length of sleep deprivation compatible with normal psychomotor reactivity, vigilance and reliable decision-making capacity; and to determine the most favorable work-rest rhythm when such a sleep deprivation occurs.

The general approach was to select the most valid and sensitive predictors of battle-efficiency (operational criteria) and to compare these predictors during the sleep loss period with psychophysiological indices of the residual level of vigilance.

The objective investigation of correlations between operational and psychophysiological parameters requires sensitive, reliable and quantifiable criteria. The following were chosen: a) for the measurement of operational criteria:- simple psychomotor performance (auditory and visual reaction time. distributed attention, radar watch-keeping with symbolic displays, thought flexibility, and memorizing complex military orders; and b) for the evaluation of fatigue and vigilance: analysis of urinary catabolities, rectal temperature and blood pressure, heart-rate and sinus arrhythmia, EEG (spectral power density, autospectra and coherence coefficient.

Thirty healthy volunteers, of the French Naval Forces, were divided into three balanced groups of 8 subjects each:

1) Group G_1 was sleep deprived for 64 hours and followed a 2 x 6 hours work/rest schedule (with normal day-night alternation).

2) Group G_2 was sleep deprived for 64 hours and followed a 2 x 8 hours work/rest schedule which tends to disrupt the normal day-night alternation.

3) Group G_3 was sleep deprived for 72 hours, and followed a a 2 x 12 hours work/rest cycle.

Each working session lasted 6, 8 or 12 hours and involved

radar detection and decision tasks, shooting, marching, grenade throwing, etc. This report describes the study and results.

57. Cameron C. (1968). A questionnaire study of fatigue in civil aircrew. (Human Engineering Note 24). Victoria, Australia: Aeronautical Research Laboratories, Australia Defense Scientific Service, Department of Supply.

A questionnaire designed to explore aspects of aircrew fatigue identified in an earlier study was circulated to over 600 pilots, navigators and engineers employed by Australian airlines on international operations. Completed questionnaires were returned by 79% of the group.

The following conclusions were drawn:

1) The complaints of fatigue which gave rise to the investigation have a reasonable basis: the majority of flight crews report severe feelings of tiredness under operating conditions which are quite regularly experienced.

2) Fatigue, as recognized by aircrew, is associated with disturbed sleep, the causes of such distubances being: (a) an irregular pattern of night and day work, with insufficient opportunity for adaptation; (b) variations in local time due to rapid traversing of time zones, again with insufficient opportunity for adaptation; (c) a chronic stress reaction among aircrew, clinically of a relatively mild nature, but important as a determinant of sleeping difficulties.

3) The contribution of environmental factors to the fatigue problem is not in itself of great importance. Low relative humidity contributes to personal discomfort and there is some evidence of dehydration among members of flight crews.

4) Gastric symptoms of a type and severity to justify a diagnosis of functional dyspepsia were reported by 25% of the aircrew group. Less severe gastric symptoms were reported by an additional 29%. Disturbed sleep was reported by 87% of the group. These figures are interpreted as evidence of a chronic stress reaction in the aircrew group.

5) There is some evidence that renal disorders occur more frequently in aircrew than in a comparable segment of the general population. A mild degree of dehydration experienced repeatedly is suspected as a contributing factor.

6) No relationship has been found between severity of fatigue and total flying hours. Individual tolerance to the factors tending to disturb sleep appears to account for variations in the severity of fatigue reported, which are independent of total hours flown.

58. Cameron, C. (1971). Fatigue problems in modern industry. Ergonomics, 14, 713-720.

A study of fatigue in civil aircrew is briefly described and a view of fatigue as a generalized response to stress is

developed. The factors associated with a fatigue reaction in aircrew are identified in the airline industry. Technological advances in other industries may be expected to bring about similar problems, notably a progressively wider adoption of shift working. Solutions may be achieved by the application of human factors principles to the full range of human factors problems in industry, and by the determination of appropriate work-rest cycles for various kinds of work.

59. Cameron C. (1973). A theory of fatigue. Ergonomics, 16, 633-648.

Early research on fatigue in industry dealt almost exclusively with variation in productive output during prolonged work. Later research, typified by studies of pilot performance, developed methods of measurement which were more sensitive to time-correlated variations in performance and were applicable to tasks which involved little physical effort. Neither approach has been outstandingly successful in uncovering the nature of fatigue phenomena.

Recent research has taken a broader view of fatigue as a generalized response to stress extending over a period of time, and has had some success in explaining the paradoxical results of earlier studies in terms of activation theory. This approach requires the time scale of fatigue studies to be extended greatly, to allow for cumulative effects over periods of days, weeks or months and for the effects of disturbed sleep habits, which appear to be very important. Fatigue effects are closely related to the effects of sleep deprivation. The importance of such long term effects suggest that the time required for recovery may be useful method of quantifying severity of fatigue.

60. Carey R. E., & Quinlan D. A. (1976). Frequent wind: Part three, execution. Marine Corps Gazette, 60 35-45.

This article describes in detail the helicopter evacuation of 6,968 persons from Saigon, Vietnam, April 29-30, 1975. Special attention was given to the multi-deck operation procedures necessitated by such a large helicopter force. Helicopter operations were continuous from first light on 29 April until the operation was completed at 0835 hours on 30 April. Elapsed flight hours for the entire operation totaled 560 hours and included 682 sorties. The high time aviator logged 18.3 flight hours and the average crew operated 13 hours. Of the 682 sorties flown during frequent wind, 360 were flown during hours of darkness. No aircraft damage was reported as a result of hostile fire; however, two aircraft were lost due to mechanical malfunctions.

61. Case H. W., Hulbert S., Mellinger R. L. (1970). Effects of fatigue on skills related to driving. (UCLA Report No. ENG-7060). Los Angeles, CA: University of California at Los Angeles School of Engineering and Applied Science. (NTIS No. PB 194-160).

The document reports on a study to determine the effects of fatigue on driving skills. The high percentage of 'driver went to sleep' accidents indicated the necessity for this type of study. The findings may add significant weight to the argument for the driver license screening examination and a countermeasure of education and perhaps stimulant drugs.

62. Chastain G. D., & Kubala A. L. (1979). Effects of fatigue from wearing the AN/PVS-5 night vision goggles on skills involved in helicopter operations. (HumRRO Technical Report No. 1217). Alexandria, VA: Human Resources Research Organization, and US Army Research Institute for the Behavioral and Social Sciences.

Reviews of the literature on rotary wing flight and interviews with aviators were conducted to determine which helicopter tasks and maneuvers are performed most frequently and/or are the most critical. Those operations found to be most critical were analyzed into perceptual and psychomotor components, and a battery of perceptual and psychomotor tests was selected to measure these factors. Aviators were tested both before and after flying with the AN/PVS-5 goggles. Eye-hand coordination was marginally affected following flight, and reaction time to lights was significantly affected.

The results described in this report indicate that fatigue resulting from night vision goggle (NVG) wear affects performance on tasks directly involved in helicopter operation. After lengthy NVG wear a general degradation in piloting ability would be expected. Efforts to limit the length of continuous use of the NVG seem prudent. The current findings should be useful in planning research designed to develop ways to reduce fatigue from NVG wear or to minimize the adverse effects of such fatigue.

63. Chastain G. D., Ton W. H., & Kubala A. L. (1979). Fatigue effects from wearing the AN/PVS-5 night vision goggles. (HumRRO Report No. FR-WD-TX-783). Alexandria, VA: Human Resources Research Organization, and US Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD A077-519/7).

This report presents an investigation of problems of discomfort and fatigue resulting from extended use of the AN/PVS-5 Night Vision Goggles. The studies specifically explored the nature of the problems encountered with the goggles, the types of abilities degraded after lengthy goggle

use, and the promise of solutions to the problems which were suggested by goggle users.

64. Chiles W. D., Alluisi, E. A., & Adams, P. S. (1968). Work schedules and performance during confinement. Human Factors, 10(2), 143-196.

Thirteen investigations were carried out as a part of an 8-year program of research on the performance effects of various work/rest schedules during confinement to a simulated aerospace vehicle crew compartment. A total of 139 subjects were tested using a standard battery of performance tasks. The synthetic work approach used provided a reliable, face-valid, and sensitive technique for assessing complex operator performance.

It was found that a man can work 12 hours per day on a 4-hours work/4-hours rest schedule for periods of at least 30 days. For shorter periods, a man can work 16 hours per day on a 4/2 schedule but at a significant cost to his reserves for meeting emergencies such as sleep loss. Circadian periodicities are found in psycho-physiological function parallelled by similar periodicities in performance functions, the latter being subject to modification by special motivational instructions.

65. Clay E. G., & Dudek R. A. (1974). Performance, recovery and man-machine effectiveness: Final report on a basic research program under project THEMIS. (USAHEL Report No. TM-9-74). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

This article summarizes five years of research directed to the problem of continuous operations. Performance changes were studied in vibrating and heated environments, under varying organizational structures and for different work-rest schedules. Physiological response was studied for various work periods, work-rest schedules, heat levels and organizational roles. Results indicate that healthy young men can work safely and effectively for extensive periods of time given certain conditions. The necessary conditions include adequate nutritional intake, change of pace activities and at least brief periods of intermittent rest.

66. Coates G. D., Kirby R. H., Eberhardt N. K., Miller S. J. (1979). Physiological influences upon the work performance of men and women. (PAL Report No. ITR-79-22). Norfolk VA: Old Dominion University, Performance Assessment Laboratory. (DTIC No. AD A081-947/4).

The synthetic-work methodology of the Multiple Task Performance Battery (MTPB) was mployed in a series of studies

designed to determine the effects of 48 hours of continuous work and sleep loss on the work performance of four groups of female subjects and one group of male subjects. The specific female groups were defined in the design by a factorial combination of the phase of the menstrual cycle at the beginning of the sleep-loss period (i.e., Menstrual vs Mid-Cycle) and whether or not the subjects were using contraceptive pills (i.e., Pill vs Normally Cycling). The performances of these four groups of female subjects were compared with those of a group of male subjects who performed the tasks of the MTPB under identical conditions; comparisons were performed during training, baseline period sleep-loss, continuous-work and a post-recovery period.

An extension of these studies subsequently compared the performance of two groups of female subjects (i.e., Normally Cycling and Pill) for an additional five weeks under normal work conditions; the purpose of this extension was to assess the effects of the phases of the menstrual cycle on work performance.

67. Coates G. G., Thurmond J. B., Morgan B. B., & Alluisi E. A. (1972). Behavioral effects of infectious diseases: Phlebotomus fever in man. Journal of Applied Psychology, 56(3), 189-201.

The synthetic work technique was employed to assess the behavioral effects of a self-limiting viral infection, Phlebotomus (or Sandfly) fever. Average efficiency, as measured with the mean percentage of baseline performance, fell about 25% with one group of 8 experimental Ss and 18% with another during the febrile period of illness. These are not as great as the 25-33% decrements in performance previously observed in more severe cases of bacterial infection with respiratory Pasteurella tularensis (Rabbit fever or tularemia). Individuals differed greatly in their behavioral reactions to infection, ranging from essentially no decrement to maximum decrements of about 14% (Sandfly fever) and 20% (tularemia) of base-line performance per degree rise in body temperature during the febrile period.

68. Cohen C. J., & Muehl G. E. (1977). Human circadian rhythms in resting and exercise pulse rates. Ergonomics, 20, 475-479. (IAA Report No. A78-13477). West Lafayette, In: Purdue University.

Circadian rhythmicity in resting, exercise and recovery pulse rates was studied on five male subjects. Resting pulse rate data were collected at seven separate times during a 24-hr period. Exercise and recovery pulse rate data were collected at the exact same times: 0400, 0800, 1200, 1500, 1800, 2100

and 2400 hr. The lowest resting pulse rates for all subjects occurred between 0400 and 0800 hr; highest resting pulse rates were between 1800 and 2400 hr. Exercise pulse rates followed this same general pattern and tended to amplify the circadian rhythmicity.

69. Collins W. E. (1976). Some effects of sleep deprivation on tracking performance in static and dynamic environments. (FAA Report No. AM-76-12). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Institute.

The influence of approximately 34 and 55 hours of sleep deprivation on performance scores derived from manually tracking the localizer needle on an aircraft instrument was assessed under both static (no motion) and dynamic (whole-body angular acceleration) laboratory conditions. In each of two experiments, 20 young men were equally divided into groups of control and sleep-deprived subjects. All tests were conducted in an enclosed Stillé-Werner rotator in total darkness with the exception of the illuminated tracking display. In both experiences, significant decrements in dynamic tracking performance were uniformly obtained after 24 hours and more of sleep loss. Static tracking scores were less consistently impaired.

In Experiment II, administration of d-amphetamine after 53 hours of sleep loss produced a sharp drop in error for both static and dynamic tracking. Although performance at both types of tasks remained poorer for sleep-deprived subjects, their static tracking scores did not differ significantly from control subjects 2 hours after drug ingestion. Thus, while the drug benefited performance, the benefits were only partial ones. Attentional lapses and inefficiency in perceptual-motor or information processing mechanisms seem to account for the deleterious effects of sleep deprivation on performance. Thus, the study indicates clear declines in performance scores for an aviation-related task after a night without sleep. These negative effects become generally greater with increasing amounts of sleep loss and are more pervasive in motion environments.

70. Colls J. E. (1974). Tests to measure performance changes in mental work. (CDL Report No. CEL-HF-19-72). Sheffield, England: Corporate Development Laboratory. (NTIS No. PB-234 291).

Body temperature follows a distinct circadian rhythm - highest in the evening, lowest in the early morning - and various authors have established that performance in simple psychological tests follows a similar rhythm. The aim of this study has been to corroborate this finding in short tests which could be used in the steel industry to predict performance, in

place of the more difficult and job specific measures such as production rate and error rate.

It was discovered that, although, there was a correlation between performance and temperature over 24 hours, this was due only to the strong night time correlation, and in fact performance fluctuated randomly during the day. In addition, during a continuous 28-hour-experiment, a marked temporary increase in performance level was recorded which coincided with the arrival of dawn. This "dawn peak" was a psychological phenomenon not reflected in a change in temperature.

71. Colquhoun W.P., Blake, M.J.F. & Edwards, R.S. (1968). Experimental studies of shift-work I: A comparison of 'rotating' and 'stabilized' 4-hour shift systems. Ergonomics, 11 (5), 437-453.

Efficiency at 'mental' tasks was observed when performed according to a time schedule imposed by following one of two different 4-hour shift systems for a period of 12 consecutive days. Twenty-eight subjects were assigned either to a 'rotating' system, in which each 4-h period of the 24 h was worked once every 72 h in a repeating cycle, or to a 'stabilized' system, in which the work periods were from 1230 to 1630 and 2400-0400 each day. In the rotating system, alterations in the level of several aspects of performance at different times of day were found to be related quite closely to concurrent fluctuations in body temperature arising from its natural circadian rhythm. A shift in the phase of this rhythm in response to the new sleep/waking cycle imposed by the stabilized system was accompanied by a corresponding change in the relative levels of performance observed in the two work periods. Thus in both systems body temperature was, in effect, a predictor of performance efficiency. Some implications for the organization of shift working are discussed.

72. Coloquhoun W., & Folkard S. (1978). Personality differences in body-temperature rhythm, and their relation to its adjustment to night work. Ergonomics, 21(10), 819-826.

A re-analysis of Blake's (1967) data indicated that the difference he obseved in the temperature rhythm of introverts and extroverts was considerably more marked in "neurotic" than in "stable" subjects. That this difference may be related to the ease with which the rhythm adjusts to a phase change is demonstated by (a) an examination of the persistence of the pre-flight rhythm immediately after an 8h eastward time-zone transition (phase advance), and (b) by an assessment of the trends in temperature during a 12h night shift (phase delay). In both cases the temperature of "neurotic" extroverts exhibited the greatest degree of adjustment. It is further shown that the temperature of extroverts is more variable day

to day than that of introverts. Taken together these findings may reflect the existence of an underlying periodicity greater than 24h in at least "neurotic" extroverts, and that (to some extent) this group may correspond with the "evening" type identified in other research.

73. Colquhoun W. P., Blake M. J. F., & Edwards R. S. (1968). Experimental studies of shift-work II: Stabilized 8-hour shift systems. <u>Ergonomics</u>, <u>2</u>(6), 527-546.

Thirty-one subjects were employed in an experiment to determine whether the relationship between efficiency at mental tasks and the circadian rhythm of body temperature observed in an earlier study was affected by an increase in the length of the duty-spell from 4 to 8 hours. Subjects were assigned either to a control "day" shift (0800-1600), a "night" shift (2200-0600) or a "morning" shift (0400-1200), and were tested for a period of 12 consecutive days on the same shift. The control shift-workers showed no consistent effects of fatigue due to the increased length of the duty-spell. Adaptation of temperature rhythm to work on the night shift was only partial, but was relatively closely reflected in the recorded performance trends. Very little adaptation to work on the morning shift was observed, and performance was thought to have been affected by partial sleep deprivation. It was concluded that body temperature was as effective a predictor of overall mental efficiency in most industrial-type shifts as in the special 4-hour shift system previously investigated.

74. Colquhoun W. P., Blake M. J. F., & Edwards R. S. (1969). Experimental studies of shift-work III: Stabilized 12-hour shift systems. <u>Ergonomics</u>, <u>12</u>(6), 865-882.

Twenty-two subjects took part in an experiment to determine whether the relationship between efficiency at mental tasks and the circadian rhythm of body temperature observed in two earlier studies was affected by an increase in the length of the duty spell from 8 to 12 hours. Subjects were assigned either to a control "day" shift (0800-2000) or a "night" shift (2000-0800), and were tested for a period of 12 consecutive days on the same shift. Some signs of fatigue due to the excessive length of the duty-spell were observed, but an underlying relationship between temperature and performance remained in evidence in some scores throughout the trial period.

Adaptation of temperature rhythm to work on the night shift was only partial, and less marked than in a previously studied "night" work situation; the partial adaptation was nevertheless relatively closely reflected in the recorded performance trends. It was concluded that the results obtained in the present and previous studies in this series demonstrated that, within certain limits, the relationship between temper-

ature and efficiency was sufficiently marked to warrant further research into its generality.

75. Colquhoun W. P., Paine M. W. P. H., Fort A. (1978). Circadian rhythm of body temperature during prolonged undersea voyages. Aviation, Space, and Environmental Medicine, 49(5), 671-678.

Circadian rhythms of oral temperature were assessed in 12 watchkeepers during a prolonged submarine voyage and compared with a "standard" rhythm obtained from non-watchkeepers ashore. Initially, the parameters of the rhythms were similar to those of the standard. However, among eight sailors working 4-h watches in a rapidly rotating cycle, considerable changes in the rhythms occurred as the voyage progressed, and concurrent alterations in sleep patterning were observed. The most characteristic change in the rhythm was a marked decline in its amplitude. In most subjects, the rhythm also tended to depart from its original circadian pattern; in at least one case, it effectively disintegrated. One subject's rhythm appeared to "free-run" with a period greater than 24h. A strong circadian rhythm was maintained in only one of these eight subjects. In four officers whose watch times were at fixed hours, adaptation of the rhythm to unusual times of sleep occurred in 2 of 3 cases where the schedule demanded it. The results are discussed in relation to the design of an optimal watchkeeping system for submariners.

76. Combat Developments Command Experimentation Center. (1963). ROAD Battalion operations in a toxic environment: Operational capability experiment. (CDEC Report No. 63-4). Fort Ord, CA: US Army Combat Combat Development Experimentation Center.

The experiment took place in four phases from January to June, 1963. One phase was conducted in Panama in order to evaluate the effects of a hot-humid environment. Fort Ord's training ranges were used to evaluate small arms firing performance; 14 battalion elements were examined in separate attack, defense, and retrograde exercises, including extended live firing by M48 tank and 106mm recoilless-rifle crews. The Battalion phase was conducted to evaluate a reinforced ROAD infantry battalion in a series of 72-hour problems that included offensive, defensive, and retrograde actions. In all phases, two different combinations of standard chemical protective clothing and equipment were worn. Normal combat clothing was also worn as a basis for performance comparison.

The major conclusions were:

1) Progressive unit ineffectiveness can be expected as a result of wearing chemical protective clothing.

2) The length of time units will remain effective will

depend primarily on outside temperature and type of physical activity. These "stay-times" will vary from less than 2 hours for an element in the assault in high temperatures to between 20 and 30 hours for an element occupying prepared defensive positions in moderate to low temperatures. The degree of encapsulation of the individual by the protective uniform will have a direct effect on stay-times when energy expenditure rates are high and outside temperatures are moderate to low.

3) Protective clothing and equipment must be modified to permit intake of liquids, adequate body heat dissipation, and improved visual and tactile use.

4) Training with protective gear and habituation to its use will reduce adverse psychological effects and improve individual performance with weapons and/or equipment.

77. Concepts Analysis Agency. (1975). Continuous combat workshop: Proceedings. Bethesda, MD: US Army Concepts Analysis Agency, War Gaming Directorate.

This report contains the proceedings of the Continuous Combat workshop held 21-22 October 1975. The purpose of the workshop was to determine the degree to which current analytic tools can measure the capability of theater ground combat forces to conduct continuous combat operations in a European environment.

For the purpose of the workshop the following definition of continuous combat was provided: Conflict over an extended area where one force attacks its opponent, or major sub-elements thereof, continuously day and night (without significant interruption) for 10 days or more.

This report records the attitudes and findings of four working groups--each of which considered a different fundamental aspect of continuous operations. Extensive common agreement was neither sought nor found in this workshop approach. There did seem to be general consensus that the prospect of continuous operations raises the level of concern over problems that exist in any case when a numerically smaller force must resist the attack of a larger one but that continuous operations themselves do not introduce entirely new concerns.

This workshop was to improve the capability to represent continuous operations in force planning war games and simulations. The observations of these proceedings make a useful contribution to assist the analytical community and agencies involved in testing and evaluation in their attempts to accomplish such simulations.

78. Creamer L. R., Wheeler D. E., & Gabriel, R. F. (1970). Human error and analysis program: Data analysis and fatigue studies. (MDC Report No. J0698/01). Long Beach, CA: Douglas Aircraft Company, McDonnell Douglas Corporation. (DTIC No. AD 869-266).

Fatigue, while frequently cited as a contributing factor in accidents, remains an elusive element in terms of definition, recognition, measurement, prediction and alleviation. Fatigue, defined as "The degradation in performance or affective state, resulting from previous work," was explored in 1968-1969 in a complex simulation experiment using an anti-submarine warfare flight trainer. Light workload over two hours and heavy workload over eight hours were imposed upon four crews. Each crew was in a controlled work environment 24-hours a day over a 2-week period. Psychological, physiological, biochemical, and performance measures were taken for individuals and for the crew as a group.

Some statistically significant effects in the physiological and blood chemistry measures were found. Bartlett's hypothesis of increased variability of performance and perceptual break-up, and the activation pattern hypothesis were to some extent verified, although it was indicated that heavier or longer loads would be needed for greater significance.

In a second study in 1969-1970, a state of fatigue, induced by continuous performance of tasks over prolonged working time, was studied in a laboratory environment. The tasks were selected to resemble the airborne activities necessary for a prolonged anti-submarine warfare (ASW) mission. Two loading conditions were imposed such that 12 subjects in a High Work Load (HWL) group worked without rest for approximately 18 hours and 12 different subjects in a Low Work Load (LWL) group worked for the same time span, but were permitted equal time on and off work, such that their workload was approximately one-half that of the HWL group. Psychological, physiological, biochemical, and performance measures were taken.

Performance decrement was observed for the HWL reflecting at least moderate fatigue. A specially designed Discrete Tracking Task was the most sensitive index of fatigue. The task was moderately difficult with almost excessive temporal demands. The HWL group also made larger time estimation errors late in the session than the LWL group. No other psychological, biochemical, or physiological variable was correlated with performance decrement (fatigue) in this study.

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79. Daugherty J. E. (1943). Effects of increased flying time on aviation instructors. War Medicine, 3, 297-302.

Twenty instructors selected at random from the first and the second training group at the Air Corps Basic Flying School were subjected to a fatigue study over a six week period, February to March 1942. The ages of the instructors ranged between 21 and 28 years, and the time spent as instructors ranged between one and sixteen months.

The average number of flying hours per person over this period was 118 hours, compared to an average of 81 hours for the same period in 1941 for another group of instructors. Including January flying time, the 20 instructors spent a total of 4,210 hours, or an average of 210 hours per man. During the same period in 1941 the total was 2,760, or an average of 138 hours per instructor, a total increase of 1,450 hours and an individual average increase of 72 hours.

80. Davies C. T. M., & Thompson M. W. (1979). Estimated aerobic performance and energy cost of severe exercise of 24 h duration. Ergonomics, 22(11), 1249-1255.

The maximal aerobic performance (VO_2 max) and energy cost of running at various speeds of two ultra-distance athletes were measured in the laboratory on a motor driven treadmill and the results related to observations made during a 24 h race. The athletes finished 1st and 2nd in the event and covered distances of 251 km and 234 km respectively during the 24 h period. From the measurements in the laboratory it was calculated that the average speeds sustained by the athletes during the competition were equivalent to an O_2 cost of 36.4 ml /(kg min) which represented approximately 50% of their VO_2 max. During the race the winner expended an estimated 77.83 kJ (18,595 Kcal) which is three times the highest recorded value in the most severe industrial work. By the nature of the activity, this figure must be regarded as at or near the upper limit of sustainable energy expenditure by man during a complete uninterrupted 24 h circadian cycle.

81. Dearnaley E. J., & Warr P. B. (Eds.). (1979). Aircrew stress in wartime operations. London, Englund: Academic Press.

This book contains important research papers in psychology and psychiatry. A special account gives the historical background to 8 research studies sponsored by the Flying Personnel Research Committee of the Ministry of Defense and first published between 1940 and 1948. The research projects examined the performance of aircrew during WW II. The projects range from statistical investigations of accidents and effectiveness, through more clinical studies of personality and individual functioning, to classic psychological experiments into fatigue and pilot error.

The book provides an insight into developments during a period when behavioral research achieved considerable advances. The flavor or the period and of research styles comes across vividly, and in this regard, the book is an important historical document and of vital interest to specialists in military studies as well as to those in aviation medicine, psychology, and psychiatry.

The articles contained include: (1) The Historical Background of Wartime Research in Psychology and Psychiatry in the Royal Air Force, (2) Clinical and Statistical Study of Neurosis Precipitated by Flying Duties, (3) The Influence of Psychological Disorder on Efficiency in Operational Flying, (4) Fluctuations in Navigator Performance during Operational Sorties, (5) Some Measures of the Effect of Operational Stress on Bomber Crews, (6) An Investigation of Landing Accidents in Relation to Fatigue, (7) The Psychological Aspects of Airsickness, (8) Experimental Study of Mental Fatigue, and (9) Pilot Error: Some Laboratory Experiments.

82. Dedmon, J.F. & Mielec, R. (1984). Customer test of the Surrogate Research Vehicle Phase 1B. (TRADOC Report No. TRMS 3-000314). Fort Knox, KY: US Army Armor and Engineer Board.

A field test of the tank-like Surrogate Research Vehicle (SRV) was conducted at Ft. Knox in 1983-84 to obtain information on command and control and nuclear, biological and chemical (NBC) considerations in extended operations. The NBC environment was simulated. Three volunteer crews were evaluated during three day/night 72-hour continuous trials. Each trial included 60 to 69 hours of simulated NBC threat whereby the crew remained in the SRV. Crews performed tactical missions and a series of cognitive tests. One M1 tank and crew were tested side-by-side with the SRV during the last trial. Data collected attempted to discern crew degradation.

83. Defayolle M., Dinand J. P., & Jacq J. (1971). Study of nocturnal vigilance in the human operator (Phase 1). Part 1, experimental procedure. (Centre de Recherches du Service de Sante des Armees, Report 245-CRSSA-PS, 1970). (English Library Translation No. 1607). Farnborough, Hants, England: Royal Aircraft Establishment.

This paper describes a program to study the sleep-inhibiting effects of certain medicinal products. The products were administered to a number of subjects who were then called upon to perform various tasks, involving alertness, during the period from 2000 h to 0600 h on each of four nights. The tasks given to the subjects and the methods of analysing the results are described. The tasks covered: (a) measurement of reaction time, (b) tests requiring maintained attention, (c) letter marking tasks (with and without a secondary task), (d) calculation tests, (e) visual detection tasks (with and without a secondary task), and (f) tests of thymic auto-evaluation.

In addition, electro-encephalograph and electro-cardiograph measurements were made throughout the periods of the tests, and these were analysed by frequency spectra and by the extraction of evoked visual potentials. No experimental results are given.

84. Dempsey C. A., Greiner T. H., Burch N. R., Chiles D., & Steel J. (1956). The human factors in long range flight. Aviation Medicine, 27, 18-22.

The human factor problems of performance, personal maintenance and measurement of stress and fatigue were studied during 56 hours continuous confinement in a grounded F-84 aircraft cockpit. Performance deterioration was associated with changes in bio-electric measurements which objectively reflect state of consciousness.

Results showed that current jet aircraft cockpits are habitable for 56 hours without major physiological stress if limited protective equipment is employed

85. DeHart R. L. (1967). Work-rest cycle in aircrewmen fatigue. Aerospace Medicine, 37, 1174-1179.

The stresses acting upon military aircrewmen are numerous and variable. These stresses are modified by such factors as morale, motivation and mission accomplishement. The interaction of stress and the individual may produce a subjective sense of weariness, with a concomitant objective deterioration in performance--an acceptable definition of fatigue.

This study was undertaken to more clearly delineate the subjective effects of fatigue in terms of the actual work-rest cycle. The subjects were highly motivated aircrewmen in an

operational squadron, performing a variety of aircraft system tests. The missions were variable, from low level ground approach tests to high level photographic evaluations; from duration times of less than one hour, to over 15 hours, and with a worldwide geographic spread.

A daily 24-hr activity log was prepared by each subject. The log was divided into five major sections: rest, duty, recreation, nutrition, and physiological reactions. Twenty-four subjects completed the study, preparing the log for 30 consecutive days, thus providing a total of 24 man-months of subjective data evaluation. The daily logs were analyzed to establish trends and the influence of duty time and other factors on subjectively described symptoms of fatigue. The importance of modifying influences of such factors as job satisfaction and mission accomplishment on subjective fatigue are presented.

86. Dessert D.M., Schuknecht L.T. & Noga G.W. (1978). Operational test and evaluation final report: Blue and gold concept. (MAC Report No. OT/E-15-13-77). Scott AFB, IL: Headquarters Military Airlift Command. (DTIC No. AD B027-081L).

C-5A missions are partially constrained by physiological limitations, specifically fatigue of the aircrews flying them. The Blue and Gold Concept employed two air refueling qualified crews on board a single aircraft. One crew was always in crew rest while the other crew perfromed normal aircrew duties. The OT&E evaluated the fatigue and its effects on the crews' performance from an operational and medical viewpoint. The operational evaluation of crew performance was based upon subjective data provided by MAC flight examiners. They evaluated the crews while acting as safety observers. The medical evaluation of crew fatigue was also based on subjective data which are historically well correlated with physiological data from previous evaluations of fatigue.

Based on both the operational and medical evaluation, this OT&E demonstrated that missions of up to 48 hours can be accomplished using this concept. No value judgment as to the inherent safety of the proposed mission design can be made from this report. The safety of this type of mission may depend on many factors, including physical and psychological characteristics of the individual crew members, the mission scenario, the direction of flight, the premission crew rest, length of duty cycles and sleep disruption.

From the operational view, crew performance appears to be the critical factor in this concept. In the Blue and Gold OT&E environment, which had a significant number of controls and constraints, the crews appeared to degrade in performance

relative to the onset of fatigue. No further conclusions are drawn regarding performance anomalies that may occur in the unstructured environment of a contingency response. From the medical view, crew fatigue is directly related to time of alert, length of duty cycles and time required for the crew to acclimatize to shifts in sleep and duty periods. Crew recovery time and turnaround time for repetitive missions were determined to be a minimum of 48 and 72 hours respectively.

The design of the missions and the restrictive nature of some of the controls placed on the OT&E may have influenced the data collected on these test missions. An evaluation of the fatigue factors being experienced by MAC crews on current "long haul" missions is recommended.

87. Dinges D. F., Orne E. C., Evans F. J., & Orne M. T. (1981). Performance after naps in sleep-conductive and alerting environments. In: L.C. Johnson, D.I. Tepas, W.P. Colquhoun & M.J. Colligan (Eds.) The twenty-four hour workday: proceedings of a symposium on variations in work-sleep schedules. (DHHS-NIOSH Report No. 81-127, pp. 677-692). Cincinnati, OH: US Department of Health and Human Services, National Institute for Occupational Safety and Health.

Situations involving quasi-continuous performance for durations beyond a usual work-day, such as those experienced by military personnel, may require an individual to remain awake for days, thereby compromising performance due to comulative effects of sleep loss. The authors investigated napping to evuluate its potential to facilitate recovery from fatigue in settings that preclude the typical eight-hour monophasic sleep cycle.

While napping appears to be an effective way to prevent some of the long-term deterioration of performance normally seen in totally sleep-deprived individuals, there is inevitable impairment of performance, called sleep inertia, immediately upon awakening from sleep. It is a serious constraint to the use of napping during quasi-continuous work setting if the individual may be required to function at full capacity, at a moment's notice and at unpredictable times. Thus, the study of this ubiquitous, transient, post-sleep performance decrement is relevant to the practical problem of implementing napping in the context of quasi-continuous performance, as well as helping to clarify basic questions concerning the nature of nap sleep and sleep stages.

The study reported here sought to explore three basic questions concerning the nature and malleability of performance immediately upon awakening from afternoon naps. These were:

1) Are both reaction time and complex cognitive performance

adversely affected following awakening from a brief nap?

2) Will an alerting napping environment and an intense waking stimulus attenuate these post-nap performance decrements? and

3) To what extent are these decrements related to different aspects of nap sleep? The experiment, and results, are described in the report.

88. Dinges D. F., Orne M. T., & Orne E. C. (1985). Assessing performance upon abrupt awakening from naps during quasi-continuous operations. Behavior Research Methods, Instruments & Computers, 17, 1, 37-45.

Quasi-continuous work settings often involve sleep loss and requirements to perform at unpredictable times. Napping may alleviate some of the sleep loss problems, but it increases the risk that the person will have difficulty functioning upon abrupt awakening. This paper describes an experimental approach, techniques, and analyses for investigating performance upon abrupt awakening from 2 hr. naps placed near either the circadian peak (P) or trough (T) in body temperature and preceded by 6, 18, 30, 42, or 54 hrs. of sleep deprivation. Five groups of healthy young adults performed quasi-continuously for 54 hrs. and were permitted a 2-hr nap at one of 5 times. Reaction time to answer a phone terminating the nap, subjective estimates, and performance of a brief, challenging cognitive task were related to nap sleep parameters of each group. Sleep deprivation increased the amount of deep in the naps and this was associated with greater post-nap cognitive performance decrements; subjective estimates were unaffected and reaction time performance was related simply to stage of sleep prior to awakening.

Circadian placement of the naps also modulated the post-nap cognitive decrement; T naps produced greater cognitive decrements than P naps, even when the latter involved more prior sleep loss. These findings have both practical and theoretical significance for evaluating the awkening process, and would not have been possible without the approach, techniques, and procedure described.

89. Dinges D. F., Orne M. T., Orne E. C., Evans F. J. (1978). Voluntary self-control of sleep to facilitate quasi-continuous performance. (Pennsylvania Hospital Report No. 70). Philadelphia, PA: Philadelphia Hospital. (DTIC AD A117-31/4).

The aim of the research has been to evaluate the potential of napping for facilitating quasi-continuous functioning. Earlier work in this laboratory isolated individual napping patterns. Replacement nappers are individuals who use naps to make up for lost sleep in anticipation of future sleep loss. Appetitive nappers nap even in the absence of fatigue because

they enjoy the experience and derive psychological benefit from the nap. Non-nappers do not find naps helpful and thus do not nap.

The current study expands these findings and explores the effect of asking individuals to nap in an environment not conducive to sleep. It also examines the effect of naps on performance. The thrust was to develop the concept of prophylactic napping as a means of training soldiers to use available slack time during quasi-continuous performance to prevent the accumulation of sleep debt, and thus maintain optimal functioning.

This report includes a review of the relevant literature on napping and fragmented sleep. Studies are discussed in relation to the program's approach to the use of napping. Findings relevant to these issues are presented, including differences in sleep efficiency, delta sleep onset, oral temperature, and the factors that influence the ease of napping.

90. Dinges D. F., Orne M. T., Orne E. M., & Evans F. J. (1980). Voluntary self-control of sleep to facilitate quasi-continuous performance. (Report No. 80). Washington, DC: US Army Medical Research and Development Command.

Quasi-continuous work schedules require individuals to function for prolonged periods with few extensive sleep opportunities. Consequently, sleep loss may jeopardize effective functioning. The aim of this research was to evaluate the potential of napping to facilitate functioning in such situations. The studies focused on identifying basic individual differences in napping behavior, and determining the implications of these differences for the ability to nap, the nature of naps, the purpose served by naps, and the consequences of napping in both sleep-conducive and non-conducive (alerting) environments. These issues are highly relevant to the implementation of prophylactic napping during sustained operations.

The authors describe an intensive study involving both laboratory and field data on sleep/wakefulness patterns, napping behavior, psychophysiology, performance, subjective activation, and circadian variation in two types of habitual nappers and a group of habitual non-nappers.

Replacement nappers nap to compensate for shortened nocturnal sleep the night before, and are the most common type of nappers. Appetitive nappers' naps are not tied to reduced nocturnal sleep; but rather may be part of a natural biphasic sleep cycle. Appetitive nappers exhibit a greater control over napping than replacement nappers. Confirmed non-nappers avoid napping because it produces unpleasant consequences for them, the basis of which might be the intrusion of a consolidated nocturnal sleep pattern into their nap.

Naps profoundly improve positive mood states in nappers, but they also yield immediate post-nap performance decrements, related to aspects of sleep infrastructure, that are relatively quickly dissipated. Alerting environments and intensive waking stimuli do little to lessen the decrements. An alerting nap environment increases the proportion of light sleep during a nap while reciprocally decreasing deep sleep, but only marginally diminishes the subjective benefits of a nap for nappers. Nappers preparing to nap show lowered activation levels. This may reflect an increased sleepiness due to sleep need, as seen in replacement nappers, or be indicative of control over daytime sleep, as seen in appetitive nappers. This preparatory response -- which appears to predict whether sleep will occur -- has implications for training soldiers to use available slack times for napping during quasi-continuous operations.

Findings are reviewed in the context of relevant literature on napping and fragmented sleep, and interpreted in terms of contemporary theories of sleep function. The authors propose that the next study involve a specific test of the efficacy of prophylactic napping to minimize the accumulation of sleep debt and its accompanying performance deficit. Future investigations should focus on factors that may enhance the control of sleep onset (without sleep debt), and the attenuation of the negative effects of sleep offset.

91. Doskin V. A., & Lavrent'yeva N. A. (1974). Periods of maximum performance and circadian rhythm of physiological functions. (NASA Technical Translation Report No. TT F-16, 310). Translation of "Periody maksimal'noy rabotosposobnosti i sutochnyy ritm fiziologicheskikh funktsiy," Sovetskaya Meditsina, Vol. 8, Aug. 1974, pp. 140-145." Washington, DC: National Aeronautics and Space Administration.

An investigation is made of maximum performance and circadian rhythm of physiological functions in students of the Moscow Medical Institute. It is concluded that periods of high performance are determined by the circadian rhythm of physiological functions.

92. Dowd P. J. (1974). Sleep deprivation effects on the vestibular habituation process. Journal of Applied Psychology, 59(6), 748-752 and (USAF SAM-TR-73-330). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine.

A Coriolis test on the USAF SAM biaxial simulator was administered to 143 pilots. Two tests were obtained on subjects in three groups: a) Subjects had no sleep for the first test, rest for the first test, rest for the second test: b) Subjects had rest for the first test, no sleep for the second test; c) Subjects had rest for both tests. A two-

parameter analog measuring the rates of decay and sensitivity co-efficients of vertical nystagmic responses, was used to compare the effects of fatigue on nystagmic responses to Coriolis accelerations.

Fatigue, in terms of moderate sleep deprivation of 24-30 hours, had significant deleterious effects on the vestibulo-ocular responses to Coriolis accelerations. Such findings indicate that fatigue physiologically makes the hazard of flying even greater.

93. Dowd P. J., & Brunstetter F. H. (1980). Crew stress and fatigue in the PAVE LOW III system. (USAF SAM Report No. TR-80-26). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A091-668/4).

The purpose of the PAVE LOW III system was to demonstrate that helicopter crews can perform combat rescue at night and in marginal weather conditions. This report discusses the PAVE LOW III system crew stress and fatigue and human factors problems encountered during combat simulated exercises. From the subjective fatigue (SF) data and self-report rating scales it appears that the system significantly stressed experienced test pilots. Workload was extremely demanding of pilot attention, skill, and alertness during terrain following-terrain avoidance, approach to hovering, and hovering maneuvers. It is recommended that the maximum flying time should be no more than 6 hours for these types of missions, and there should be at least 8 hours of uninterrupted sleep or 12 hours of crew rest between missions. Attention should be given to improving the following features: seating, acoustic insulation, display illumination, maps and holders, and communication and ventilation systems.

94. Drew G. C. (1979). An experimental study of mental fatigue (FPRC Report No. 227,). In: E. F. Dearnaley, & P. B., Warr (Eds.), Aircrew Stress in Wartime Operations. London: Academic Press.

The work reported in 1940 was an attempt to study the effects of mental fatigue on a simulated flight task. Special care is taken to separate mental from muscular fatigue because the two are thought not to be entirely analogous. The experiments were conducted in a specially designed Spitfire fighter cockpit mockup in which instrument readings could be mechanically recorded. Subjects were instructed to perform a series of maneuvers such as climbing, diving, and turning. Each series was defined as a "course unit." Each subject performed seven "course units" separated by level flight segments, approximately two hours elapsed time, during the experiment. Others did the tasks for 6-7 hours. Error scores were calculated for airspeed, altitude, turn and slip, compass

heading, climb and/or dive, and rate of climb.

Performance deterioration resulted from subjective changes in the pilot's attitude which resulted in (a) pilot's lowering his own performance standards, (b) pilot's splitting the task up into small, seemingly unrelated, tasks, and (c) pilot's becoming preoccupied with physical discomforts. Some of the performance decrement was also attributed to the instrument panel layout. Some general design changes are discussed to remedy the instrument panel problems.

95. Drucker E. H., Cannon D. L., & Ware R. J. (1969). The effects of sleep deprivation on performance over a 48-hour period. (HumRRO Technical Report No. 69-8). Alexandria, VA: George Washington University, Human Resources Research Office.

An experiment was conducted to determine, for extended periods of work, the effects of (a) working for 48 hours work periods at night compared with starting in the morning, and (c) rotating jobs. Teams performed a driving task and a target detection task; a control group performed the same tasks, but with provisions for work without sleep, and that deterioration occurs primarily at night, or during the subjects' normal sleeping hours. Job rotation to introduce another activity did not prevent performance decrements.

96. Dudek R. A. (1972). Performance, recovery, and man-machine effectiveness. (Texas Tech. Univ. Themis Report No. 603). Lubbock, TX: Texas Tech University Center of Biotechnology and Human Performance. (DTIC No. AD 738-916).

Emphasis is placed on the determination of optimal or near optimal work/rest schedules for individuals and crews to yield high performance with minimal decrement over time followed by recovery (after rest) to an acceptable high performance. The experimentation is further aimed at consideration of various task levels and differing conditions of environment. Experimentation in progress continues to focus attention on the assessment of human performance under continuous operations or relatively long term activity (2 hours or more of activity).

97. Duncan C. E., Sanders M. G., & Kimball K.A. (1980). Evaluation of Army aviator human factors (fatigue) in a high threat environment. (USAARL Report No. 80-8). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

Questionnaire data received from student and instructor pilots located at Fort Rucker, AL, indicate significant levels of fatigue when flying in different flight altitudes and profiles; the lower the altitude flown, the more rapidly pilots experience fatigue. These data suggest standard flight is 1.4 times as fatiguing as day standard flight; day terrain flight

is 1.3 times as fatiguing as day standard flight; night terrain flight, the most difficult flight profile examined, is 1.97 times as fatiguing as day standard flight. US Army Regulation 95-1, January 1980, sets a maximum of 140 hours per month per aviator of day flight in a combat environment. Existing doctrine emphasizes nap-of-the-earth (NOE) techniques, and if so accomplished for 140 hours, could possibly result in an unsafe and severely fatigued helicopter pilot. Using the guidelines presented in this report, field commanders may organize their crew work/rest schedules and more effectively continue their mission in Army aviation.

98. Dureman E. I., & Boden C. (1972). Fatigue in simulated car driving. Ergonomics, 15(3), 299-308.

The aim of this study was to assess the effects of four hours continuous driving in a car simulator on (a) performance (number of steering errors and brake reaction time), (b) subjective fatigue, (c) pulse rate, respiratory rate, skin resistance and neck muscle tension, (d) intra-subject correlations between the latter variables and performance over time. An additional aim was to study these psychological and physiological measures when arousal was stimulated by the pairing of an electric shock with steering errors. To control training effects the Ss repeated the experiment twice.

The results showed that all subjects had a progressive performance decrement over time in parallel with increased feelings of fatigue. There was also a decrease in pulse rate and respiratory rate. Skin resistance showed continuous increment over time. Covariations over time between performance variables and physiological variables were rather high in most individuals; e.g for pulse rate with frequency of steering errors, and EMG with frequency of steering errors. The expectation of an electric shock in connection with steering errors yielded higher subjective and autonomic arousal, slower performance decrement over time, and also lowered variability, both within and between subjects for all the variables recorded.

E

99. Eberhard J. W. (1968). Sleep requirements and work-rest cycles for long term space missions. Paper presented at the 1968 Human Factors Society Convention in Anaheim, CA. Arlington, VA: Matrix Corporation.

This analysis tried to piece together data found in various industrial studies of the influence of sleep-wakefulness cycles on productivity, basic research studies applying physiological and psychological indices, results from space flight simulation studies, and finally, the data released from the long term American space flights that occurred to mid-1966.

The review of the literature indicated: (a) There seems to be inadequate data relating the application of earth-oriented sleep/wakefulness cycles in long-term space missions; (b) the Gemini flights shift from a four-four schedule to one of eight hours tended to verify this for long-term missions; (c) the 14 day Gemini 7 flight seemed to indicate that an extended flight gradually requires less sleep: (d) if mission oriented tasks require astronauts to perform on other than 8 hours consecutive sleep, consideration should be given to the effectiveness of different sleep periods from 2 angles: (1) selecting astronauts who require sufficiently less sleep, and (2) preconditioning the astronauts to use the different sleep/wakefulness cycle; (e) more definitive work should be done on the area of split sleep schedules if such schedules should be required for future long-term space missions; (f) more data are required on the influence of zero "g" on sleep requirements; and (g) consideration should be given to testing the period of wakefulness as related to the critical mission oriented tasks and astronaut performance of those mission oriented tasks to be performed upon sudden awakening.

100. Ellingstad V. D., & Heimstra N. W. (1970). Performance changes during the sustained operation of a complex psychomotor test. Ergonomics, 13(6), 693-705.

Fifteen male subjects were exposed to a primary tracking task and a variety of subsidiary tasks for a total of 15 hours. Tracking performance was assessed through the use of two error measures: amount of time off the target track, and number of times off target. Subsidiary performance tasks

included: a vigilance task requiring subjects to respond to the deflection of the needle of a small meter; two reaction time tasks requiring response to the onset of one or the other of two lights; mental multiplication, which required the solution of simple multiplication problems; and digit span, in which the subject was required to repeat as rapidly and as accurately as possible a set of digits of either 5, 6, or 7 numbers in length. In addition, three physiological measures were obtained.

A significant decrement in tracking performance was obtained for both measures. This decrement was not particularly abrupt in its occurrence but rather took place cumulatively over the entire course of the experiment. There was no clearly established performance decrement on the subsidiary tasks used in this investigation. A marked variability in performance over the course of the experimental session was characteristic of performance on these tasks. Performance on the vigilance task, and one of the reaction time tasks improved during the 15-hour test session.

The 17-Ketosteroid and 17-Hydroxycorticoisteroid values increased during the session but only in the case of of the latter was the increase significant. The eosinophil count of subjects exposed to the test conditions decreased steadily throughout the experimental session. However, eosinophil measures obtained from control subjects increased during a similar time period.

101. Emanski J.J. (1977). Continuous land combat. (SRI Technical Report No. 4940). Menlo Park, CA: SRI International. (DTIC No. AD A052-802).

This report presents the results of a study of continuous land combat, a concept of modern warfare made possible by the complete mechanization of land combat forces and the technology that enables effective combat at night, in poor weather, and under low visibility conditions. It is a logical extension of the blitzkreig warfare of the German Armies in World War II.

An abbreviated comparison is made of current U.S. perception of and capabilities for the conduct and support of continuous land combat with the land and air force needs to achieve that capability. A systems perspective was taken in examining combat supporting functions and the essential elements of a continuous combat capability - doctrine, organization, training, equipment and technology. An effort was made to gain the participation and input of those operational and development organizations that are concerned with various aspects of continuous land combat operations.

102. Engel J. D., & Bishop H. P. (1971). A partially annotated bibliography on optimal work-rest cycles. (HumRRO Consulting Report). Alexandria, VA: Human Resources Research Organization. (DTIC No. AD A020-655).

This bibliography is not an exhaustive survey of all studies relating to task efficiency, fatigue,or distribution of performance. It reviews those studies whose results would assist in the eventual selection of optimal work-rest cycles for specified types of performance. Only a few laboratory experiments clearly dealt with the work-rest cycling question. It became necessary to examine the results of a number of other studies which were less directly concerned with the question but were pertinent. In general, the studies were those in which observations of performance extended for a period of 24 hours or longer since it was felt that such a period of observations was the minimum necessary for valid applicability to the scheduling of work and rest over prolonged intervals.

103. Englund, C.E. & Krueger, G.P. (1985). Methodological approaches to the study of sustained work/sustained operations: Introduction to special section of Behavior Research Methods, Instruments, & Computers. Behavior Research Methods, Instruments, & Computers, 17 (1) 3-5.

This article introduces 12 other articles illustrative of methodologies used in research on sustained/continuous operations. The articles resulted from a "sustained operations research" workshop conducted at the Canadian Defence Civil Institute of Environmental Medicine and from an American Psychological Association symposium entitled "sustaining work hours without decrements in productivity". Both meetings were held in Toronto in August 1984.

The article defines extended operations as jobs or tasks that proceed continuously with only a short break or breaks, but that operate within a typical shift system for lengthy periods, longer than a normal duty day. The worker knows he/she will be relieved or able to rest. It defines sustained operations as planned or unplanned, goal-oriented, nonstop continuous performance/operations without rest or sleep in which the worker is expected to keep going as long as he/she can. Both obviously have very important worker performance and behavioral implications.

104. Englund C. E., Naitoh P., Ryman D. H., & Hodgdon J. A. (1983). Moderate physical work effects on performance and mood during sustained operations (SUSOPS). (NHRC Report No. 83-6). San Diego, CA: US Naval Health Research Center.

During times of emergency, e.g., military operations, humans must often work continuously for long hours at physically demanding tasks while remaining mentally alert. In this repeated measures study, eleven pairs (one experimental and one control) of Marines (N=22) experienced one 12-hour baseline and two 20-hour continuous work episodes (CWE). The 20-hour CWEs were separated by five hours which included a 3-hour nap from 0400-0700. Each hour of CWE was split into two half-hour sessions. During the first half-hour subjects performed alphanumeric (A-N) visual vigilance tasks. The experimental member of each pair spent this first 30 minutes also walking on a treadmill in full combat gear (25 kg) at approximately 31 percent max VO_2 heart rate for a total distance of approximately 114 km. The controls performed the A-N task sitting quietly at a video terminal. During the second half-hour, all subjects completed mood and fatigue scales and performed selected combinations of tasks. Biomedical and electrophysiological sleep recordings were obtained on both subjects.

Mood scales showed that subjects expressed significantly more fatigue and expressed more negative affect during the second sustained operation. No significant sleep stage changes were found. Generally, after nap performance (0800) was not significantly different than CW1 ending performance level. The physical workload did not affect performance, but sleep loss and circadian effects produced performance decrements in some tasks.

From a comparison with previous NHRC nap studies the authors concluded that the timing and duration of the nap are important in determining recuperative value. When designing work/rest schedules to maintain high quality performance in recurring CWEs as short as 20 hours, a 3-hour or longer nap during the circadian nadir may be required.

105. Englund C. E., Ryman D. H., Naitoh P., & Hodgdon J. A. (1985). Cognitive performance during successive sustained physical work episodes. Behavior Research Methods, Instruments & Computers, 17, 1, 75-85.

In modern life some occupations require continuous work (CW) for sustained periods. Military operations can last over 24 h, and, the preferred logistics for the lengths and timing of naps or rest periods to minimize performance loss due to physical effort or sleep loss are not fully known. This study analyzed various cognitive performance measures to determine if

and when certain abilities degrade with CW and exercise of 45 h with only a 3-h nap midway. Twenty-two Marine reconnaissance personnel were studied over two CW days. Eleven of these (exercise group) walked on a treadmill with pack (20 kg) at 30% of maximal oxygen uptake (VO_2 max) for the first half hour of 17 one hour sessions each CW period while the others (controls) worked at a video terminal. They both performed an alpha-numeric task during this half hour to determine their long term visual vigilance. This task consisted of randomly appearing letters or numbers in which the subject responds to only the A's and 3's. During the second half hour of every session other sets of tasks were given including: a four choice discrimination task, word memory, reading comprehension speed reading tasks, and a logical reasoning test of complex information processing. At other periods before, during, and after the CW days, map, shape and building location memory, and a task of radar missile simulation were given.

The results indicated that the exercise of treadmill walking did not accentuate or attenuate sleep loss effects on the cognitive measures studied. Sleep loss (day differences) was significant for the visual vigilance task (CW1 = 80.9%, correct; CW2 = 70.6%). Choice reaction and logical reasoning primarily showed time-of-day differences with early morning performance worse. Sleep loss effects during the first day were observed in the word memory task, again with early morning recall worst. There was continued low, word memory performance in the morning of the second day indicating no recovery following the nap. Visual vigilance degraded earlier in the second day for the controls than for the experimental subjects who were exercising during this task. Two reading comprehension measures showed complex differences over the days or between groups over sessions, with lower reading performance in the evening (1800).

These findings indicate that exercise at 30% of VO_2 max does not compound sleep loss effects in cognitive performance. Indeed physical activity during video terminal monitoring may delay any sleep loss decrement. Variability of many cognitive abilities throughout the day appeared to show a greater effect than the sleep loss and exercise effects over two days.

106. Ernstein, J. (Ed.), (1983) <u>Sustained intensive air operations: Physiological and performance aspects</u>: Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338). Loughton, Essex, United Kingdom: Specialised Printing Services Ltd. (DTIC No. AD A139-324).

The Symposium addressed the aeromedical and human factors aspects of the capabilities of aircrew and ground crew to

perform their duties at high intensities at irregular times of the day and night over many days or weeks under the operational conditions which would occur in war. The Symposium included (i) four papers on the operational scenarios of sustained intensive air operations with particular emphasis on air defense and offensive operations, (ii) eleven papers reporting laboratory studies on the measurment of aircrew workload, the effects of disturbances of circadian rhythms and deprivation of sleep and the use of hypnotics and stimulants to influence sleep and wakefulness, (iii) six papers on the effects of NBC protective equipment and procedures on air and ground crew with particular reference to fast jet and helicopter operations, (iv) eight papers reporting field studies of fatigue, performance and physiological disturbances in aircrew and ground personnel engaged in sustained air operations including the South Atlantic Campaign, and (v) a panel discussion on the requirements for future research into the physiological, psychological and aeromedical aspects of sustained air operations and the potential value of current aeromedical knowledge to the NATO air forces.

107. Evans F.J., & Orne M. T. (1975). Recovery from fatigue. (Pennsylvania Hospital Report No. 60). Philadelphia, PA: Pennsylvania Hospital. (DTIC No. AD: A100-347/4).

With the aim of evaluating the potential of napping for facilitating unimpaired continuous performance over long periods, four interrelated studies were carried out:

1) 430 young adults were administered a specially developed questionnaire to elicit nighttime and daytime sleep patterns. Parametric findings are reported.

2) Based on questionnaire responses, supplemented by an extensive interview, individuals typical of three response patterns were selected: (a) replacement nappers--those who use daytime sleep to make up for lost nighttime sleep, (b) appetitive nappers--those who derive psychological benefit from daytime sleep regardless of fatigue, and (c) confirmed non-nappers--those to avoid napping because they 'feel worse afterwards than before.'

A subsample of 33 individuals typical of these three groups took a one-hour afternoon nap where physiological and psychological parameters were recorded.

3) These subjects were subsequently requested to keep a 14-day sleep diary which permitted a more detailed analysis of the relationship between daytime and nighttime sleep. Several interesting and reliable differences between these groups in the physiological nature of naps and the consequences of napping were identified.

4) A collaborative study was carried out with the University of Louisville Performance Research Laboratory to evaluate the

effectiveness of two short-term cognitive measures used in our past research to assess the restorative effects of napping on performance.

108. Evans F. J., & Orne M. T. (1976). Recovery from fatigue. (Pennsylvania Hospital Report No. 65). Philadelphia, PA: Pennsylvania Hospital. (DTIC No. AD: A011-340).

The findings of the original napping questionnaire (based on 430 students) on differences between appetitive and replacement nappers, and between nappers and non-nappers, have been extended in a new sample of 469 students. This served to validate several important conclusions about the functions of napping in the different subgroups. A special subgroup of subjects who were selected as appetitive nappers by the questionnaire but as replacement nappers by a blind interviewer were also studied. This group was termed stress nappers because they seem to nap in response to stress-induced sleep disturbances. Moreover, their nap seems to be less restorative and may interfere with the subsequent night's sleep. This kind of napping pattern appears less useful in preventing fatigue but might be prognostic of future psychopathology.

The central concept underlying the work concerns individual differences in the ability to control sleep processes. Unless such control can be taught to individuals not possessing the skill, attempts to teach prophylactic napping would be unsuccessful. The voluntary control of sleep processes may reflect a more general ability to control altered states of consciousness; consequently, the authors also explored the relationship between responsivity to hypnosis and aspects of the napping questionnaire.

F

109. Fiorica V., Higgins E. A., Lategola M. T., Davis A. W., & Iampietro P. F. (1970). Physiological responses of men during sleep deprivation. (FAA Report No. AM-70-8). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Institute. (NTIS No. PB 713-590).

The effects of 84 hours of sleep deprivation were examined in a group of six young men and compared with a group of six controls. Subjects were studied in pairs, one sleep-deprived and one control. Primary attention was given to the responses to acute whole body cold exposure in terms of internal body and skin temperature changes, oxygen consumption changes and plasma catecholamine levels. Psychomotor performance was evaluated at 4-hour intervals over the course of the sleepless period and the patterns of urinary excretion of catecholamines, magnesium, and creatinine were followed. After the first sleepless night, psychomotor performance of sleep-deprived subjects was significantly lower than that of control subjects. The ability to regulate body temperature during standardized cold exposures, however, was not impaired by the loss of sleep. Urinary excretion patterns for the two groups were similar, except for differences related to activity level. It is suggested that, despite the gross psychomotor changes observed during sleep deprivation, physiological regulating systems are relatively unaffected by sleep loss.

110. Flight Safety Foundation, Inc. (1971). Human factors in long distance flight. Arlington, VA: Flight Safety Foundation, Inc.

This text was prepared in cooperation with the Flight Safety Foundation, the Federal Aviation Administration and the Aluminum Company of America to provide an awareness and understanding of human factor safety considerations involved in the use of corporate and commercial aircraft for long distance flights at irregular hours.

The circadian rhythm is clearly defined. In simplified language, time-travel formulas as evolved by the International Civil Aviation Organization in order to minimize effects of circadian rhythm disruptions are described.

There are sections on fatigue, flight-time limitations, crew duty times, alcohol, and high altitude flying with symptoms of hypoxia. There is a brief discussion of symptoms of hyperventilation and descriptions of other effects of atmospheric pressure changes including aerotitis, gastrointestinal distension, aerosinusitis, aerodontia, bends, air embolism and chokes. Air turbulence is mentioned and other emergency and survival techniques including materials and procedures.

111. Folkard F., & Monk T. H. (1979). Shiftwork and performance. Human Factors, 21(4), 483-492.

The recent increase in the incidence of shiftwork has been accompanied by a change in the type of task typically performed by the shiftworker. The technological advances which have produced both these effects have meant that the shiftworker is more likely to be engaged in cognitive, mentally taxing tasks than the predominantly perceptual-motor ones typical in earlier times. Contemporary research on time of day effects in performance efficiency has indicated that these task changes may be crucially important in determining on-shift performance, and hence the choice of the individual and shift system that is most suitable. Evidence is reviewed on task demands, the effects of different shift systems, and the role of individual differences.

A descriptive model is proposed in which on-shift performance is seen to be dependent on the type of task, type of shift system, and type of person, with the three factors interacting via the worker's various circadian rhythms.

112. Folkard S., Knauth P., Monk T. H., & Rutenfranz J. (1976). The effect of memory load on the circadian variation in performance efficiency under a rapidly rotating shift system. Ergonomics, 19(4), 479-488.

Experimental shift work studies have typically found body temperature and performance efficiency to show very similar circadian rhythms. However, the performance tasks used have placed little, if any, reliance on short term memory. Studies of the variation in performance during the normal waking day have found performance on most tasks to improve over the day but on short term memory tasks to decrease.

This paper reports an experimental study of the performance of two subjects on a rapidly rotating (2-2-2) shift system. Three versions of a new performance test, each with a different memory load, were administered four times per shift. With the low memory load version, performance showed a high positive correlation with body temperature and was poor

during the night shift. However, with the high memory load version, performance was negatively correlated with temperature and was best during the night shift. It is concluded that future shift work studies must take into account the memory load of the task under investigation.

113. Francesconi R. P., Stokes J. W., Banderet L. E., & Kowal D. M. (1978). Sustained operations and sleep deprivation: effects on indices of stress. Aviation Space and Environmental Medicine, 49(11), 1271-1274.

Two groups of highly-trained and motivated military personnel were deprived of sleep while sustaining performance of their assigned military tasks in a laboratory simulation. One team (I) was deprived for 48 h while the second team (II) was deprived of sleep for two 39-h periods separated by a 33-h rest interval. Six-hour urine samples were collected on a 24-h basis after an appropriate control period for each team. During sleep deprivation, each team performed its functions as members of an artillery fire direction center (FDC) in response to a sustained simulated combat scenario.

Results suggested that anticipation and perception of the experimental situation affected the common urinary indices of stress. For example, team I, informed that they might be required to sustain operations for 86-h, had significant increases in both urinary 17-hydroxycorticosteroids (17-OHCS) and total catecholamines. Alternatively, team II, realizing that each of their sustained operations challenges would not exceed 42 h, had significantly decreased 17-OHCS due largely to decrements in the usually high outputs recorded between 0600-1200 hours. Analogously, total catecholamines were significantly reduced after 24 and 30 h. Conclusions were that, under these conditions, generally similar effects are noted for sympathicoadrenomedullary and adrenocortical activity. Further, the responses are affected by situational uncertainty as well as apparent cumulative fatigue.

114. Fraser D. C. (1957). A study in fatigue in aircrew, IV: Overview of the problem. (FPRC Report No. 984). Farnborough, England: Institute of Aviation Medicine, Royal Air Force, Flying Research Committee. (DTIC No. AD 130-087).

This paper examines the evidence available from research on certain fatigue-inducing factors. Some of these factors include: the length of flight for both piston and jet powered aircraft, night versus day flying, and cumulative fatigue. On the basis of the research cited, several conclusions were drawn:

1) A significant fatigue effect occurs in subjects tested after flying continuously for more than ten hours in piston powered aircraft.

2) A significant fatigue effect occurs in subjects tested after three one-hour sorties in a jet fighter aircraft during the day, or two one-hour sorties at night.

3) The fatigue effect involved in night flying is greater than day flying of equivalent length.

4) Marked changes in performance can occur without any very extensive detectable physiological changes.

115. Frazier T. W., Benignus V. A., Every M. G., & Parker J. F. (1971). Effects of 72-hour partial sleep deprivation on human behavioral and physiological response measures. Falls Church, VA: BioTechnology, Inc. (DTIC No. AD 732-872).

Ten adult males were subjected to partial sleep deprivation experiments in order to study the effects of progressive sleep deprivation on the basic biological rhythms underlying performance on signal detection tasks and to assess the value of using change in biological rhythms as an objective measure of human response to such types of stress. The data obtained were subjected to a power density spectral analysis with a program based upon the Fast Fourier Transform. The results show that signal detection measures, response latency, and heart rate are all highly sensitive in reflecting progressive loss of performance capability. Power spectral data also show changes as a function of sleep deprivation, indicating that one feature of this type of stress may be an alteration of basic human biorhythms.

116. Froberg J. E. (1975). Psychophysiological circadian rhythms: A literature review. FOA Reports, 9(6), 1-27. Stockholm, Sweden: Forsvarets Forskningsanstalt, National Defence Research Institute. (NTIS No. PB 251-936).

After a short presentation of terminology and theory in the field of circadian (about 24-hour) rhythms, the literature is reviewed as concerns circadian rhythms in physiological arousal, performance, and subjective arousal. Studies on relationships between these sets of variables, as well as investigations regarding sleep deprivation, personality factors, and circadian rhythms are discussed. It is concluded that, although a large number of studies have been reported, relatively few of them meet stringent methodological criteria, and very few have been concerned with the simultaneous measurement of several indicators of psychophysiological functioning.

117. Froberg J. E. (1978). Task complexity and 24-hr performance patterns in morning and evening active subjects. (FOA Report No. C 52001-H6). Stockholm, Sweden: Forsvarets Forskningsanstalt, National Defence Research Institute.

One "morning active" and one "evening active" group of subjects were deprived of sleep for 72 hours. Measures of performance in a coding task were obtained at three different levels of complexity, and in conditions with an incentive or an auditory disturbance, respectively. The results showed that complexity of the task did not affect 24-hour patterns in performance, while the other two conditions tended to enhance performance in the morning hours, and this was especially pronounced in the morning active group.

118. Froberg J. E. (1979). Performance in tasks differing in memory load and its relationship with habitual activity phase and body temperature. (FOA Report No. C-52002-H6). Stockholm, Sweden: Forsvarets Forskningsanstalt, Research Institute of National Defence. (NASA No. N80-22974/3).

Twenty-four hour patterns in tasks differing in memory load were studied during a 75 hour vigil. Differences in performance were also studied between morning and evening active subjects, and between body temperature and performance rhythms. The task with a high memory load showed a 24 hr rhythm which was in inverse phase with the less memory loaded task and with body temperature. This was true only for the first 24 hr cycle, after that the memory loaded task tended to follow the other two variables, except in the case of the most extreme morning types for whom the inverse relationship continued to exist.

119. Froberg J., Karlsson C. G., Levi L., & Lidberg L. (1970). Circadian variations in performance, psychological ratings, catecholamine excretion and urine flow during prolonged sleep deprivation. Prepared in cooperation with Karolinska Sjukhuset, Stockholm (Sweden). Lab. for Clinical Stress Research. (DTIC NO. AD 748-059).

The paper presents two experiments, in which a total of 63 subjects were deprived of sleep for 75 hours with simultaneous 3- hourly measurements of physiological variables (e.g. catecholamine excretion), self-ratings, and performance. The purpose of the experiments was to study: (a) circadian rhythms in a number of biochemical and psychological variables under controlled conditions. (b) changes in these variables with the duration of sleep deprivation. (c) temporal interrelationships between the biochemical and psychological variables. In all the above respects, the first experiment was an exploratory study, the results being further tested in the second.

120. Froberg J. E., Karlsson C. G., Levi L., & Lidberg L. (1975). Psychobiological circadian rhythms during a 72-hour vigil. Forsvarsmedicin, 11, 192-201. (NTIS No. PB-261 296).

Circadian rhythms in urinary catecholamine excretion, oral temperature, performance, and subjective arousal (self-ratings of alertness and fatigue) were studied in 32 subjects deprived of sleep for 72 hours. Adrenaline excretion, oral temperature, and subjective arousal showed consistent circadian variations. Performance rhythms were also apparent, although more irregular, in some of the measures. Noradrenaline excretion had no significant circadian rhythm. The crest phase for adrenaline excretion was between about 1200, and 1500 hours for subjective arousal and performance about 1600-1700 hours, and for oral temperature about 1700-2300 hours. There were significant correlations between oral temperature, performance, and subjective arousal.

121. Frost J. D. (1975). Skylab sleep monitoring Experiment M133. (NASA Contract Report No. 9-12974). Houston, TX: The Methodist Hospital.

Astronauts on pre-Skylab missions commonly complained of insomnia, and in some cases periods of sleep loss degraded crew performance. Investigation of this situation was important in planning future long-term flights; subsequently, the first objective measurements of man's ability to obtain adequate sleep during prolonged spaceflight were made during the three Skylab flights.

Electroencephalographic, (EEG) and electro-oculographic (EOG), and head-motion signals were acquired during sleep by use of an elastic recording cap containing sponge electrodes and an attached miniature preamplifier/accelerometer unit. A control-panel assembly, mounted in the sleep compartment, tested electrodes, preserved analog signals, and automatically analyzed data in real time (providing a telemetered indication of sleep stage).

One astronaut was studied per flight, and while there was considerable individual variation, several characteristics were common to all three: (1) Stage 3 sleep increased inflight and decreased in the postflight period. (2) Stage 4 was consistently decreased postflight, although this stage was variable inflight. (3) Stage REM (rapid eye movement) was elevated, and REM latency decreased in the late postflight period (after day R+3). (4) The number of awakenings during sleep either showed no change or decreased inflight.

In only the 28-day mission was there a significant decrease in total sleep time; in that case it was a result of voluntarily reduced rest time and was not due to difficulty in sleeping nor frequent awakening. The subject on the 84-day

mission experienced some difficulty in the first half of the flight, showing a decreased total sleep time and increased sleep latency, but this resolved itself with time. Sleep latency presented no problem in the other flights. While many of the findings are statistically significant, in no case would they be expected to produce a noticeable decrement of performance capability.

These findings suggest that men are able to obtain adequate sleep in regularly scheduled eight-hour rest periods during extended space missions. It seems likely, based upon these results, that the problems encountered in earlier spaceflight did not arise from the zero-g environment per se, but possibly were a result of more restricted living and working areas in the pre-Skylab spacecraft.

G

122. Gartner, W. B., & Murphy, M. R. (1976). Pilot workload and fatigue: A critical survey of concepts and assessment techniques. (NASA Report No. TN-D-8365). Moffett Field, CA: National Aeronautics and Space Adminisstration Ames Research Center.

This study addresses the principal unresolved issues in conceptualizing and measuring pilot workload and fatigue. These issues are seen as limiting the development of more useful working concepts and techniques and their application to systems engineering and management activities. A conceptual analysis of pilot workload and fatigue, and a discussion of current trends in the management of unwanted workload and fatigue effects are presented. Refinements and innovations in assessment methods are recommended for enhancing the practical significance of workload and fatigue studies.

123. Geier R.P. (1979). Sleep loss: A debt that must be paid. Armor, Jan.-Feb., 37-38.

A short magazine article outlining the potential impact of sleep loss on tank crews and other battlefield soldiers. Provides a short list of "tips" of what to expect from sleep loss and how to cope with such impending conditions of the babblefield. One-liners summarize important findings from applicable military research on sustained operations.

124. George C.E. & Dudek R.A. (1974). Performance, recovery and man-machine effectiveness: Final report on a basic research program under project THEMIS. (HEL Report No. TM 9-74). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

Five years of research directed to the problem of continuous operations are summarized. Performance changes were studied in vibrating and heated environments, under varying organizational structures and for different work-rest schedules. Physiological response was studied for various work periods, work-rest schedules, heat levels and organizational roles.

Results indicate that healthy young men can work safely

and effectively for extensive periods of time given certain conditions. The necessary conditions include adequate nutritional intake, change of pace activities and at least brief periods of intermittent rest.

125. Gibbs C. B., Leornado R., & Rowlands G. F. (1968). The effects of psychological stress upon decision processes and the speed and precision of tracking movements, 1: Study of the effects of sleep deprivation and disturbance. (NRC Report No. NRC-10397, ML-2). Ottawa, Ontario, Canada: National Research Council of Canada. (NTIS No. N69-10528).

Twelve youths were deprived of sleep for 48 hours. Each subject was tested for 15 minutes at four-hourly intervals on each of two tasks: mirror tracing and step input tracking, using an instrument named the stressalyzer. The same subjects were again tested one week later. They were then allowed to sleep whenever they wished, but were aroused at four-hourly intervals in the night, some 15 minutes before the times, near 1:00 a.m. and 5:00 a.m. at which they were tested during the previous study of complete sleep deprivation. Sleep deprivation of 48 hours produced little or no deterioration in the group performance in mirror tracing, but tracking ability on the stressalyzer deteriorated sharply after 20 hours without sleep, with a further large decrease in skill at the 36-hour stage of testing.

126. Glenville M., & Wilkinson R. T. (1979). Portable devices for measuring performance in the field: The effects of sleep deprivation and night shift on the performance of computer operators. Ergonomics, 22(8), 927-933.

The performance of 12 computer operators was measured in the field, on two new portable tests of reaction time, during the first night of the shift at 0400 h and at the beginning day shift (0500 h), over three successive three-week comparisons. The results were: mean reaction time increased significantly on the night shift as compared with the day; and the adverse effect of the night shift was absent during the first comparison and became increasingly apparent on the second and third replications. These results: 1) provide evidence of inferior performance on the night as compared with the day shift in the field; 2) show that data from previous studies of sleep deprivation in the laboratory are able to provide a good indication of what to expect in the field; and 3) emphasize the need for longitudinal studies in order to assess the true effects of stressful influences.

127. Graeber R.C., Cuthbert B.N., Sing H.C., Schneider R.J. & Sessions, C.R. (1980). Rapid transmeridian deployment: Cognitive performance and chronobiologic prophylaxis for circadian dyschronism. In: Proceedings of the Army Science Conference, April 1980. (pp 73-77). Washington, DC: Department of the Army, Office of the Deputy Chief of Staff for Research, Development and Acquisition.

Rapid deployment of combat units to overseas locations is a primary concern of today's strategic planners. Such movements require the airlifting of units across multiple time zones. Adverse physiological and behavioral consequences accompany the rapid crossing of three or more time zones. These effects result from the requirement that the body must adjust its circadian rhythms to the new local time.

Under normal conditions, these daily cycles are synchronized by the external Zeitgebers (time-givers) of the local environment. The sudden shifting of these Zeitgebers causes the shifting at different rates of the body's physiological, biochemcial and behavioral rhythms. While some circadian rhythms adjust quite rapidly, others adjust very slowly. Consequently, the passenger's circadian system is not only out of synchrony with the environment but is also internally desynchronized. It is the latter condition, circadian dyschronism which is particularly responsible for the fatigue and malaise typically reported as "jet lag" during the first several days following rapid transmeridian flight.

The physiological and behavioral consequences of such flights pose a potentially serious problem for troops required to display maximal combat effectiveness upon arrival at a hostile destination. The high level cognitive performance required by the modern sophisticated battlefield may only serve to exacerbate the problem. Any reduction of the adverse effects of rapid deployment would enhance combat readiness. Consequently, the authors designed a set of experiments to test a series of chronobiologic countermeasures which may hasten physiological and behavioral adaptation to new time zones. Two military deployment studies employing various jet lag countermeasures are described.

128. Graeber R. C., Sing H. C., & Cuthbert B. N. (1981). The impact of transmeridian flight on deploying soldiers. In L.C. Johnson, D.I. Tepas, W.P. Colquhoun & M.J. Colligan (Eds.) The twenty-four hour workday: proceedings of a symposium on variations in work-sleep schedules. (DHHS-NIOSH Report No. 81-127). (pp. 641-675). Cincinnati, OH: US Department of Health and Human Services, National Institute for Occupational Safety and Health.

There is a growing military concern over our readiness to deploy combat units rapidly overseas. Such airlifts require a

sudden shift in the work-sleep schedule of deploying soldiers. These shifts are dictated by the crossing of multiple time zones during the flight. The physiological and behavioral consequences of rapid transmeridian flight may be a potentially serious problem for troops expected to fight with maximal effectiveness upon arriving at their destination. The modern, high technology battlefield leaves little room for performance failures due to "jet lag."

In designing countermeasures for use with eastward deploying soldiers, the authors followed the basic notions of Ehret's diet plan model in conjunction with the manipulation of social cues, light-dark cycles, and rest-activity patterns which are known to be effective synchronizers of human circadian rhythms.

The basic strategy in two studies was to induce a more rapid phase advance of the circadian system by controlling the timing of rest-activity schedules, social interaction, meals, and caffeine/theophylline consumption.

The countermeasures were tested in two field studies with troops deploying from the U.S. to West Germany. Subjects in the first study were 179 male soldiers being transferred overseas as a unit in October, 1978. The study design divided the participants into an experimental aircraft (n = 84) and a control aircraft (n = 95); both flights departed the U.S. in mid-day and arrived in Germany early the next morning, CET.

Oral temperature was recorded from all subjects. A subsample of 15 soldiers in each group was studied more intensively: in addition to temperature, measures taken at each test session included addition of random pairs of single digits, four-choice reaction time, a fatigue checklist, and a 24-hour diary of sleep, eating and drinking, bowel movements, and physical illness symptoms. Subjects in these "intensive" subgroups, all living in the barracks, were tested every four hours around-the-clock for four days about two weeks prior to departure. Baseline measurements for the remaining subjects were taken at 0800, 1200, and 1600 only, as these subjects lived off-post and were unavailable outside of normal duty hours. All subjects were tested every four hours for six days after arrival in Germany.

The second study, comprising two distinct experiments, was carried out in January, 1979 during a NATO field training exercise from the central U.S. to Germany. Conditions differed markedly from the first study. Extreme winter weather prevailed on both sides of the Atlantic, and in Germany troops lived in field tents.

Training and baseline testing were carried out for both experiments during the week immediately prior to deployment from the troops' home post. Formal testing was conducted for four days, with three test periods each day roughly corresponding to breakfast (0800), lunch (1200), and dinner (1630) times. Following deployment (+7 hours), troops were tested for 3 to 5 days beyond the day fo arrival. An additional night test (at about 2100 hours) was added so that four test sessions were held each day after arrival.

Fatigue and sleep. The primary complaint of persons experiencing "jet lag" is fatigue with a corresponding desire for sleep. The countermeasures appeared to be effective in this regard. The experimental subjects slept for a significantly shorter time as compared to control soldiers during the first two days in Germany

129. Grandjean E. P. (1968). Fatigue: Its physiological and psychological significance. Ergonomics, 11, 427-436.

Physiologists very often consider fatigue simply as a decrease in physical performance. Psychologists try to consider it as a condition affecting the whole organism, including factors such as subjective feelings of fatigue, motivation, and, of course, the resulting deterioration of mental and physical activities. The term "fatigue" is thus often used with different meanings and is applied in such a diversity of contexts that it has led to a confusion of ideas.

This paper attempts to give, in the light of neurophysiological knowledge, a clearer notion of what could be defined and understood b "fatigue." It does not, however, deal with muscular fatigue, but with what is usually called general fatigue.

130. Grandjean E. P. (1970). Fatigue. American Industrial Hygiene Association Journal, 1, 11.

In light of present neurophysiological knowledge we may consider fatigue as a state of the central nervous system controlled by the antagonistic activity of the inhibitory and activating system of the brain stem. The regulating systems in turn are susceptible to reaction to stimuli from the surrounding world, to stimuli from the conscious part of the brain, and to humoral factors originating within the organism and having obviously the task of regulating recovery and wakefulness.

Recent investigations on human beings gave results matching well this neurophysiological concept of fatigue. Significant correlations were found between characteristic changes of the EEG and psycho-physiological changes, and

between psychophysiological performances and subjective feelings of fatigue. We may conclude that these procedures are adequate for measuring fatigue related to workload and to monotony.

131. Grandjean E. P., Wotzka G., Schaad R., & Gilgen A. (1971). Fatigue and stress in air traffic controllers. Ergonomics, 14(1), 159-165.

Fatigue was measured on 68 air traffic controllers using the following methods: critical fusion frequency (CFF), tapping test, grid tapping test, self-rating. The measurements were taken 9 times within 24 hours over 3 weeks. Stress was measured on the basis of a questionnaire and of catecholomine excretion in urine. The four fatigue tests showed significant agreement. There was a marked decrease in the values after the 6th hour of work. During the night hours, the test values were lower, and the subjects stated they were more tired. For the first work hour and for the 9th to 11th work hour, significant correlation was found between (a) CFF and grid tapping; (b) CFF and self-rating "refreshed-tired"; and (c) between grid tapping and self-rating "refreshed-tired". This means that subjects with a marked decrease in CFF or in grid tapping performance have a greater tendency to "tired" in the self-rating test. On the basis of this finding it might be hypothesized that all measures are indicative of a common state of fatigue.

Of 62 subjects: in difficult situations 60 subjects felt nervous, tense, irritated, 13 were anxious and and trembling, 19 had increased perspiration, 14 had increased pulse rate and heart ache, 25 suffered from insomnia and chronic fatigue.

Urine samples from 6 subjects were taken after normal office work, easy ground control work, and radar air traffic control. There was a significant increase in the catecholamines in the last condition.

132. Gray S. F. (1980). Forty-eight versus twenty-four hour duty for USAF missile crews: A feasibility study using subjective measures of fatigue. (USAF SAM Report No. TR-80-39). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine.

The purpose of this study was to assess the feasibility of implementing a 48-hour work schedule for missile launch crews of a U. S. Air Force operational missile wing. A 90-day field test using two operational Minuteman missile squadrons as test and control groups was accomplished during the winter of 1978-79 at Grand Forks Air Force Base, North Dakota. Subjective reports of fatigue and the quantity and quality of sleep were recorded daily by crew members during work and while they were

off duty. In addition, subjective reports of workload and disruptions of sleep were gathered during alerts.

Subsets of data from at most 10 distributed alerts for each crew were tested for differences between the responses of crew members working a new 48-hour vs. those working a standard 24-hour schedule. Scaled subjective reports of fatigue at the end of alert, after driving back to base, and after 24 hours of recovery indicated no significant differences between the two work schedules. A statistically significant difference between work schedules was found in the hours slept at home during the first night of recovery. Members of the test group (48-hour work schedule) increased their sleep during recovery by 2.1 hours over sleep on the night previous to the alert. Members of the control group (24-hour work schedule) increased their sleep during recovery by a mean value of 1.3 hours over the pre-alert quantity.

This finding was interpreted as the result of having a greater "opportunity" to sleep which the test group was provided, rather than from a greater "need" to sleep resulting from the strain associated with the schedule. Other variables measured were not significant.

H

133. Hackman K. D., Larson E. E., & Shinder A. E. (1978). Analysis of accident data and hours of service of interstate commercial motor vehicle drivers. Washington, DC: Bureau of Motor Carrier Safety. (NTIS No. PB 286 718).

This report presents the results of an analysis of the relationship between commercial motor vehicle accidents and the hours of service and rest of drivers regulated by the Bureau of Motor Carrier Safety. A total of 25,666 single and two-man truck accidents and 483 bus accidents, that occurred during 1976, were analyzed from data on Motor Carrier Accident Report Forms and a special supplementary driver service and rest report form. A limited volume of driver exposure data was available for comparative analysis.

The topics covered in this report include: the hours of service regulations; driving, duty fatigue and accidents occurring between periods of extended rest; rest and the use of a sleeper berth; driver age, experience and physical condition; cyclic patterns, and, carrier and vehicle characteristics.

134. Haggard D. F. (1970). HumRRO studies in continuous operations. (HumRRO Report No. 7-70). Alexandria, VA: Human Resources Research Organization. (DTIC No. AD 705-705).

A lab and field study were conducted to obtain data on performance decrements on tank crew tasks during 48 hours of continuous combat operations, and to examine the degree of decrement in terms of its effect on tactical efficiency. Experience in the studies illustrates the need for increased efficiency in obtaining human factors information, demanded by the increasing complexity of military tactics and equipment.

135. Halcomb C. G., & Blackwell P. J. (1969). Report on Project THEMIS. (DTIC No. AD 703-918).

Vigilance, or monitoring behavior, has been of interest to researchers since World War II. Research activity has not only continued over the past 25 years, but has increased at an ever progressing rate. This bibliography was compiled to meet the need for a continuing program of research into the problem

associated with recovery from the classical vigilance decrement, and is presented with annotations in the hope that it will be of value to investigators in the field.

136. Hale H. B., Hartman B. O., Harris D. A., Williams E. W., Miranda R. E., & Hosenfeld J. M. (1972). Time zone entrainment and flight stressors as interactants. Aerospace Medicine, 43, 1089-1094.

Physiologic responsiveness to flying was studied, using the members of a double-crew of a C-141 aircraft during six flights, each of which lasted 54 hours and involved bi- or tri-directional transmeridian flying. Responsiveness was quantified by means of endocrine-metabolic indices (urinary epinephrine, norepinephrine, 17-hydroxycorticosteroids, urea, sodium and potassium), using urine specimens which were collected at 4-hour intervals during the flights.

Physiologic entrainment was shown to be a factor contributing to responsiveness, for there was rhythmic variability which related to time of day at the crews' home base. The waveforms, amplitudes, time relations and overall levels, however, did not agree with those of unstressed persons. Preflight factors had carryover influence, acting as intensifiers of flight induced elevations at first, but gradually becoming less influential. As judged by epinephrine, norepinephrine and 17-OHCS, refractoriness toward flight stressors consistently developed at 2200 hours (Eastern Standard Time), even after the crew had crossed many time zones (flying either eastward or westward). These hormones indicated hyper-responsiveness regularly at 0600 hours EST; at other times responsiveness was shown (by these same indices) to be moderate. Potassium, on the first day, indicated low responsiveness at 2200 hours and transient hyper-responsiveness at 0200 hours.

On the second day, in association with sustained subjective fatigue of moderate degree, potassium indicated persistent noncyclic hyper-responsiveness. At the same time 17-OHCS indicated persistent hyper-responsiveness, although the factor of entrainment had modifying influence. Urinary sodium indicated cyclic change in responsiveness to flight, as did urea, but these two metabolic indices were out of phase with the hormones and potassium.

137. Hale H. B., Kratochvil C. H., Ellis J. P. (1958). Plasma corticosteroid levels in aircrewmen after long flights. (USAF SAM Report No. TR 59-15). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A036-037/CST).

The Sweat fluorescence method of determination of hydrocortisone and a corticosterone-like fraction in blood was employed in an attempt to evaluate flying fatigue in a group of 44 aircrewmen participating in flying activities in military aircraft. Preflight values for each of the two steroid fractions agreed with those of Sweat for normal male subjects, but significant increases in both fractions were noted after flights of 9 to 12 hours' duration. These changes are not of the nature of normal diurnal variations.

138. Hale H. B., Storm W. F., Goldzieher J. W., Hartman B. O., Miranda R. E., & Hosenfeld J. M. (1973). Physiological cost in 36- and 48-hour simulated flights. Aerospace Medicine, 44(8), 871-881. (DTIC No. AD 766-384).

Groups of young healthy men were studied during 36- and 48- hr simulated flights in which they performed on psychomotor measuring devices, using a 2-hour work/rest schedule. Physiologic cost was assessed by use of a battery of urinary techniques, including potassium, sodium, urea, 17-OHCS, and, in some cases, individual 17-ketosteroids. Comparison was made of responses to (a) uncomplicated flight, (b) flight complicated by environmental dryness, (c) flight complicated by 8,000-ft pressure altitute, and (d) flight complicated by dryness and altitude. The prolonged psychomotor effort (and attendant sleep deprivation) acted as a nonspecific stressor. Altitude had intensifying influence, but dryness tended to counteract some phases of the stress response. In combination, altitude and dryness in certain physiologic respects acted in a depressant manner. Complete recovery from such prolonged effort required more than 2 days.

139. Hale H. B., Williams E. W., & Buckley C. J. (1969). Aeromedical aspects of the first nonstop transatlantic helicopter flight: III. Endocrine-metabolic effects. Aerospace Medicine, 40, 718-723.

Endocrine-metabolic appraisal was made by means of urinalysis for all participants (2 crews of 5 men each) in the first nonstop, transatlantic helicopter flight. Serial urine specimens were analyzed for epinephrine, norepinephrine, 17-hydrocorticosteroids, urea, creatinine, phosphorus, magnesium, potassium and sodium. Non-specific stress was evident, as flight caused 143 percent gain in epinephrine, a 25 percent gain in urea and a 51 percent reduction in the norepinephrine-

epinephrine ratio. It also modified the circadian trends for 17-OHCS and phosphorus. The inter-individual endocrine-metabolic variability was high.

140. Hall D. A., Townsend R. E., Knippa J., & Pruett R. (1980). The impact of remote fly-away submersible operations on personnel endurance capabilities. (NHRC Report No. 79-52). San Diego, CA: US Naval Health Research Center. (DTIC No. AD A093-706/0).

To obtain information on stress, fatigue, and work-rest cycles of submersible operators and system support personnel members during an actual submarine rescue fly-away mission, 17 fly-away team members were monitored during the conduct of a 10-day simulated open-sea submarine rescue using the Deep Submergence Rescue Vehicle (DSRV), AVALON. Operators and crew members lived aboard the mother submarine which carried the DSRV from port to the site of the downed submarine and return. Demographic information, psychological measures, and environmental data were obtained during baseline, transit-out, in-port, and dive periods. The overall results supported previous findings, suggesting that a DSRV mission of the present duration and difficulty can be accomplished without exceeding the capabilities of the crew and support personnel. The trend of the changes, does, however, suggest that missions of longer duration may require scheduling of regular sleep periods for personnel to maintain performance.

141. Hall D. H., Townsend R. E., & Knippa J. (1980). Changes in mood, fatigue, and work-rest cycles associated with deep submersible operations. (NHRC Report No. 80-5). San Diego, CA: US Naval Health Research Center. (DTIC No. AD A091-589/2).

As deep submergence vehicles (DSVs) develop greater depth capibilities and are given duration missions, the physiological and psychological well-being of the operator and surface support personnel (SSP) take on increasing importance in insuring successful completion of the task. Establishment of baseline data on stress and fatigue in submersible operators and SSP is important in determining the safety of present operations and the reserve capability available in the event of unanticipated demands to perform.

To obtain information on mood, fatigue, and work-rest cycles of both submersible operators and surface support crew members during actual operational dives in the open sea, 7 operators and 18 SSP were monitored during two separate multi-week evolutions using the DSVs TURTLE and SEA CLIFF. Operators and crew members lived aboard the surface support ship MAXINE D and made 15 dives, some in excess of 6,000 FSW.

Demographic information, psychological, physiological and performance measures, and environmental data were obtained during pre-deployment, transit-out, dive, nondive, transit-in and post-deployment periods. The results suggested that disruptions in sleep-wake cycles caused by repetitive deep submersible operations may impair accuracy and efficiency on a variety of mental and physical tasks.

142. Harris D. A., Hale H. B., Hartman B. O., & Martinez J. A. (1970) Oral temperature in relation to in-flight work-rest schedules. Aerospace Medicine, 41, 723-727.

Six experimental flying missions (each of 54 hours duration) were flown in a C-141 aircraft. Two crews took turns flying the aircraft during eac mission. The same two crews flew all six missions. In three of the missions the work/rest schedule was 4/4 hours; in the remaining mission it was 16/16 hours. Oral temperatures of 9 of the crewmembers (2 aircraft commanders, 2 co-pilots, 2 flight engineers, 2 navigators and 1 loadmaster) were measured at 4-hour intervals during the flight periods and also during 54-hour postflight periods, with the testing schedule standardized with respect to time of day.

The oral temperature rhythm during flight periods, although remaining entrained to the time at the home base, was lower in amplitude than that during postflight periods. The 4/4 work-rest schedule had more depressant influence on oral temperature than the 16/16 schedule. The individuals occupying key positions had the lowest oral temperature during flight periods as well as during post-flight periods.

143. Harris D. A., Pegram G. V., & Hartman B. O. (1971). Performance and fatigue in experimental double-crew missions Aerospace Medicine, 42, 980-986.

Six experimental transport missions using a double crew were flown in a C-141 on routes generating various combinations of long and short legs. Crews followed a 4/4 or 16/16 work/rest schedule within operational constraints. On-board crew rest facilities were provided so that the plane could fly through the airlift system without crew changes or crew delays. The missions required approximately 55-60 hours to complete. The flying time averaged around 43 hours. Crew performance was evaluated by ratings made by an on-board flight examiner.

There were no significant differences in flight examiner ratings. Subjective fatigue was measured by a rating scale. There were no significant differences related to work/rest cycles. There were significant differences related to mission profile and crew position. Sleep EEGs were recorded on the two

navigators and were supplemented by self-reports from all crewmembers. There was a marked reduction in total sleep as well as Stage 1-REM and deep sleep. Findings are discussed in relation to the demands of flying transport missions.

144. Harris W., & O'Hanlon J. F. (1972). A study of recovery functions in man. (USAHEL Report. No. TM-10-72). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory. (DTIC No. AD 741-828).

Concepts of sustained and continuous military operations were examined with respect to relevant literature. In particular, the objectives were to predict behavioral and biological impairments which might result in those operations; and to determine whether the period necessary for recovery following a sustained operation can be ascertined from the literature. It was concluded that those objectives could not be met due to inadequate information. Nonetheless, the literature did provide data which suggest that certain severe impairments may be experienced by soldiers engaging in sustained and continuous operations. It also provided guidelines for the design of studies to collect the required information. Finally, this review led to a call for serious re-evaluation of the current concepts of continuous operations.

145. Hartley L. R. (1974). A comparison of continuous and distributed reduced sleep schedules. Quarterly Journal of Experimental Psychology, 26, 8-14.

After a night of normal sleep, 36 subjects were divided into three groups of 12. One group was allowed to continue sleeping normally, one group had four hours continuous sleep and the third group had three 80-min periods of sleep distributed throughout the 24-h period, for the next four days. Subjects were given a visual vigilance test on each day. Overall performance was better following distributed than following continuous reduced sleep, but worse than following 8 h of sleep. The main difference between the reduced sleep groups was in their decision criterion. This difference mainly reflected the difference in time since the two groups had last slept.

146. Hartman B. O. (1965). Fatigue effects in 24-hour simulated transport flight--changes in pilot proficiency. (USAF SAM Report No. TR-65-16). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine.

Each of four pilots completed a 24-hour simulator flight broken into eleven 2-hour legs terminated by an Instrument Landing System (ILS) landing. Two kinds of performance measures are presented: (a) 20-second time-lapse photographs

recorded airspeed, altitude, and rate of climb (or compass heading) through cruise portions of each leg; and (b) the ground-track record of the ILS approach was photographed after each landing.

The cruise portions of each leg showed an increasing variability in performance, but this change did not significantly reduce overall system efficiency. Instrument approaches were carried out at a high level of proficiency for approximately 20 hours, at which point there was a precipitous drop in performance.

147. Hartman B. O. (1967). Psychological factors in flying fatigue. International Psychiatric Clinics, 4, 185-196.

This review summarizes the controversies and problems found in the study of aircrew fatigue concentrating on the facts useful to practicing flight surgeons and physicians. Definitional aspects are avoided while the role of such factors as changes in work efficiency and subjective changes are discussed. These factors are determined by a host of forcing functions which are subdivided into three main groups: environmental, situational and personal factors. These factors are discussed with regard to the type of fatigue occurring (acute, cumulative and chronic), and the effectiveness of the crewmen during normal and extended flights.

148. Hartman B. O. (1971). Field study of transport aircrew workload and rest. Aerospace Medicine, 42, 817-821.

Selected transport crewmembers flying 100 logistics missions maintained a log on work and rest on an around-the-clock basis starting 12 hours prior to the mission and ending after 3 days of post-mission rest. Ninety missions were flown to Southeast Asia and 10 to Europe. The average mission time was 6.7 days, during which the crew flew 44.5 hours. The full cycle, including pre-departure and post-mission crew rest, was 9.1 days. Logged work on the average mission accounted for 44.5% of mission time. The remainder was spent in an "off-duty" status. In the analyses, special attention was given to self-report of sleep. Crewmen slept somewhat more while out on a mission than during pre-departure (7.3 h versus 6.8 h). During the post-mission crew rest, they slept considerably more (9.9 hours on day 1; 9.2 h on day 2; 8.9 h on day 3). This finding on sleep is discussed in relation to fatigue and sleep disturbances.

149. Hartman B. O., Benel R. A., & Storm W. F. (1980). A review of USAFSAM studies employing multiple-task performance devices. (USAF SAM Report No. TR 80-16). USAF School of Aerospace Medicine, Brooks Air Force Base, TX. (DTIC No. AD A087-272).

A review of apparatus development at the USAF School of Aerospace Medicine to measure the performance and proficiency of systems operators. The devices are all classified as multiple-task performance batteries that were designed to measure efficiency in the general sense. The bulk of this paper consists of summaries of studies, some of them on the topic of sustained operations with aircrew personnel.

150. Hartman B. O., & Cantrell G. K. (1967). MOL: Crew performance on demanding work-rest schedules compounded by sleep deprivation. (USAF SAM Report No. TR-67-99). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine.

Thirteen subjects took part in a series of 12-day runs in an experiment on the effects of demanding work/rest schedules (4/2, 4/4, or 16/8 hours). On days 8, 9 and 10, subjects were deprived of sleep and worked continuously. No significant work/rest effects were seen until subjects were sleep-deprived. In general, subjects on the 16/8 schedule tolerated sleep deprivation better and recovered faster, as evidenced by psychomotor test scores and sleep reports.

151. Hartman B. O., & Cantrell G. K. (1967). Sustained pilot performance requires more than skill. Aerospace Medicine, 38, 801-803. (NATO/AGARD Report No. CP 14). (DTIC No. AD 661-165).

The impact of factors such as management, job satisfaction and workload was clearly demonstrated in research during WW II. A study of crew workload in the C-141 provided data which could be used to analyze living and working schedules during extended missions. A model mission was empirically derived and demonstrated major disruptions in the daily patterns of eating, sleeping and working. Situational factors associated with flying through several time zones appeared to have a primary effect. Actual reports from the field supported these findings. While it is reasonable to hypothesize that these and similar factors should reduce the aircrewman's physical and psychological fitness for sustained flying proficiency during demanding missions, the crucial studies remain to be done.

152. Hartman B. O., & Ellis J. P. (1977). Arousal and sleep disturbance: Biochemical considerations. NATO Advisory Group for Aerospace R & D. (NATO/AGARD Report No. LS-105, pp, 6-34). London: Technical Editing and Reproduction Ltd.

This is a wide-ranging paper which starts with the underlying biochemistry and the elucidation of mechanisms, as well as the rationale for selecting some measures in preference to others. It describes an illustrative study, giving a glimpse of the utility of amino acid assays in stress research. It reviews over a dozen studies from the USAF School of Aerospace Medicine laboratory, displaying the historical trend, and the multiplicity of operational factors which have been evaluated. The authors also describe a few more recent studies, more behaviorally oriented, and two reviews. The behavioral side of this kind of research is examined in a second paper elsewhere. There is reasonable congruence between-behavior and biochemistry provided the examination of such a relationship is sufficiently global. Certainly when behavioral measures indicate no more than mild stress, the biochemical measures agree. When global, qualitative terms for the stress of a particular occupation, like "mild," "moderate," "severe," are used, there is considerable support and agreement between the two approaches.

153. Hartman B. O., Hale H. B., & Johnson W. A. (1974). Fatigue in FB-111 crewmembers. Aerospace Medicine, 45, 1026-1029.

Fifteen biomedically dedicated missions of 8 hours duration were flown in the FB-111 fighter aircraft as part of its initial operational evaluation. Each two-man crew provided data on subjective fatigue, discomfort, efficiency, and pre- and post-mission sleep. In addition, urine samples obtained from one crew on an unusually demanding mission were analyzed for epinephrine, norepinephrine, 17-hydroxycorticosteroids, sodium, potassium, and urea. The data showed that the crews experienced moderate fatigue and stress, aggravated by physical discomfort, from which they recovered after one night of sleep.

154. Hartman B. O., Hale H. B., Harris D. A., & Sanford J. F. (1974). Psychobiologic aspects of double-crew long-duration missions in C-5 aircraft. Aerospace Medicine, 45, 1149-1154.

Subjective fatigue and oral temperature were used as biomedical indices in a study in which two C-5 jet transport crews alternately operated the aircraft. Data collected at 4-hour intervals during and following four 66-hour missions (each a roundtrip intercontinental flight) clearly established that these dissimilar functions were rhythmic, and flight factors exerted modifying influence on both rhythms. Particularly

significant was the finding that subjective fatigue on the average showed (a) initial latency, (b) an intensification phase, and (c) a reversal endocrinemetabolic and sympathetic nervous system hyperactivity (compensation). Oral temperature and subjective fatigue responses to prolonged flight tended to run parallel courses. Recovery rates for subjective fatigue and oral temperature tended to be similar, and at least 3 days were needed for elimination of residual flight effects.

155. Hartman B. O., Storm W. F., Vanderveen J. E., Vanderveen E., Hale H. B., & Bollinger R. R. (1974). Operational aspects of variations in alertness. (NATO/AGARDogaph No.189) London: Technical Editing and Reproduction Ltd. (DTIC No. AD 786-123).

Variations in alertness undoubtedly affect operator performance, sometimes to a degree which significantly degrades operational effectiveness. Alertness is a biological state with behavioral, urophysiological and biochemical elements. Related states are vigilance, attention, and arousal. This monograph summarizes the literature on these topics, as well as the influence of various environments on alertness levels, spontaneous fluctuations in alertness, and effects of such variation on operator performance. The environments under consideration include long duration flights, flights at night, monotonous tasks, solitude, mild hypoxia, and variations in thermal condition in a flight compartment.

156. Haske R. (1974). Behavior of circadian rhythm of temperature and temperature and performance after two subsequent transatlantic flights. (DLR Report No. FB 74-02). (Forschungsbericht 74-55). Bonn-Bad Godeserg, Germany: Deutsche Forschungs-und Versuchsanstalt fur Luft-und Raumfahrt.

Circadian rhythms of temperature and performance were studied in 8 students in 3-hour-intervals during periods of 24 hours after a jet flight from Germany to the USA and vice versa with a stay of 24 hours in the USA. Two 24-hour preflight periods revealed the basic normal daily rhythm of temperature and performance. The effects of a 6 hour time shift after the 24-hour stay in the USA were evaluated by determining temperature and performance parameters on day 1, 3 and 5 following the flights. A considerable desynchronization with the local time was observed after flights. The resynchronization-time amounted up to 3-5 days in Germany afterwards.

157. Haslam, D.R. (Ed.),(1978) The effect of continuous operations upon the military performance of the infantryman (Exercise "Early Call" II). (APRE Report No. 4-78). Farnborough, Hampshire, United Kindgom: Army Personnel Research Establishment.

Ten experienced infantry soldiers took part in a 9-day tactical defensive exercise during winter months. A 90-hour period without scheduled sleep preceded a 6-day period with four hours block sleep per 24 hours. Two-day control periods preceded and followed this 9-day phase. Assessments were made of shooting, vigilance, cognitive functioning, mood, physical fitness, and military effectiveness. Level of awareness was monitored by means of 24-hr EEG recorders worn by all 10 subjects throughout the trial.

Results indicate that tasks with a vigilance and cognitive component began to deteriorate after one night without scheduled sleep. After 3 nights without sleep, performance on these tasks was, on average, approximately 50% below the initial level. On the third night without scheduled sleep military observers judged the section to be militarily unreliable in a defensive role. It was found that 4 hrs of block sleep on the fourth night considerably improved performance and mood. After a total of 12 hrs scheduled sleep, i.e. a further 8 hrs, performance had recovered, generally speaking, to 80% - 100% of control values.

Throughout the exercise, in which the amount of physical activity was moderate, there was no physiological evidence of deterioration in physical fitness; there was EEG evidence of alterations in cerebral function. Thirty hours of rest following the 9-day exercise eliminated any residual performance decrement, and restored cheerfulness and vigor.

158. Haslam D.R. (1981). The military performance of soldiers in continuous operations: Exercises "Early Call" I and II. In: L.C. Johnson, D.I. Tepas, W.P. Colquhoun, & M.J. Colligan (Eds.), The twenty-four hour workday: Proceedings of a symposium on variations in work-sleep schedules. (DDHS NIOSH report No.81-127, pp. 549-580). Cincinnati, OH: National Institute for Occupational Safety and Health.

In Early Call I, three infantry platoons, (68 participants) adopted a defensive role against a small number of "enemy" troops, and maintained a tactical situation for 9 days. The trial was divided into 5 exercises, during each of which a defensive position was prepared and occupied. Exercises 1 (2 days) and 5 (3 days) were the control periods with 6 hrs sleep per night in the field and Exercises 2,3 and 4 (3 days each) were the experimental or sleep deprivation periods. After the first control period, each Platoon was assigned a sleep schedule: 3 hrs sleep, 1.5 hrs sleep and 0 hrs

sleep in 24 hrs. The 9-day sleep deprivation period consisted of a 3-day sequence of events which was repeated 3 times in different locations; thus a defensive position was prepared and occupied for 3 days before moving to a new one. Activities included digging and camouflaging, wiring, mining, patrolling, ambushing, sentry duty and radio operating.

Objective measures included assesments of shooting (vigilance shooting and shot grouping), weapon handling, cognitive functioning and physical fitness. Subjective assessments were made by military observers and the subjects themselves.

All of the 0-hours sleep platoon withdrew from the exercise by Day 4, after 4 nights without sleep; 39% of the 1.5 hrs sleep group left by Day 5; 48% of the 1.5 hrs sleep group and 91% of the 3 hrs sleep group completed the exercise. More specific results on the performance tests are presented in the report. Recovery was complete after 3 days rest in camp.

Early Call II was for 3.75 days of continuous activity followed by 6 days when there was limited opportunity for sleep. Ten infantry participants had no scheduled sleep for the first 90 hours of the trial; then 4 hrs block sleep in every 24 hrs for the following 6 days. Again, defensive positions were dug, camouflaged and occupied. Surprise attacks by the "enemy" were countered. Mine laying, mine clearing, first aid and "casualty" evacuation activities were carried out. Shooting, cognitive functioning and physical fitness were assessed.

Cognitive and vigilance tasks began to deteriorate after one night without sleep, and after 3 nights without sleep, performance on these tasks was considerably impaired. The introduction of 4 hrs block sleep following 90 hrs in which there was no scheduled sleep (and very little unscheduled sleep) had a marked beneficial effect upon performance and mood, and an average amount of 19.5 hrs sleep at the end of the 9-day trial eliminated any remaining decrement.

In summary, in exercises without combat stress, the effects of sleep loss are psychological rather than physiological; even small amounts of sleep are beneficial; with increasing sleep deprivation, there is an increasing liklihood of physiological sleep patterns developing in the brain; a hostile weather climate interacts with sleep loss and influences "survival times.

159. Haslam D. R. (1982). Sleep loss, recovery sleep, and military performance. Ergonomics, 25(2), 163-178.

Ten experienced infantry soldiers completed a 9-day (216 hours) tactical defensive exercise, the aim of which was to determine if soldiers are likely to remain militarily effective during a period of partial sleep loss following a period with no scheduled sleep at all. Assessments were made of shooting,

vigilance, cognitive functioning, EEG activity and physical fitness. The results indicated that tasks with a vigilance and cognitive component began to deteriorate after one night without scheduled sleep. After 3&3/4 days (90 hours) with no scheduled (and very little unscheduled) sleep, 4 hours block sleep had a marked beneficial effect upon performance. After a total of 12 hours sleep over 3 days (72 hours), performance recovered (except at 0545 hours) from an approximate average level of 50 to 88% of control values. 30 hours of rest, of which an average amount of 19 1/2 hours was spent asleep, eliminated any remaining decrement.

Electroencephalographic (EEG) recordings indicated that on the six nights following total sleep loss there was an increased percentage of stage 4 sleep. Stage REM percentage remained virtually unchanged, except for the first night after total sleep loss, when there was 8% less. The EEG results are discussed in relation to the work of other investigators.

160. Haslam D. R. (1983). The incentive effect and sleep deprivation. Sleep, 6(4), 362-368.

In order to examine the effect of a small amount of sleep following 3 3/4 days (90 h) of wakefulness, 10 infantry soldiers took part in a laboratory-based experiment. At the end of the vigil, a 2-h sleep was preceded and followed by a cognitive test session consisting of encoding and decoding. In order to simulate a realistic situation, subjects were not told the scheduled length of their vigil until a few hours before their 2-h sleep. Following the test-sleep-test period, 27 h were allowed for sleep and rest. Results indicated that after 3 nights without sleep, performance was, on the average, 55% of the control values. During the test session before the 2-h sleep, performance improved by 30%, to 85% of control values, indicating the considerable effect that incentive can have on even severely sleep-deprived subjects.

The reserve mental capacity demonstrable during sleep deprivation indicates the caution that is needed if the effects of "undiluted" sleep loss are sought; it also emphasizes once again the lack of knowledge concerning the function of sleep.

161. Haslam, D.R. (1984) The military performance of soliders in sustained operations. Aviation Space and Environmental Medicine, 55(3), 216-221.

Two 9-day tactical defensive exercises were carried out. The first assessed and compared the performance of three platoons of infantry scheduled for either 0, 1.5, or 3 h of sleep in every 24 h, and the second determined whether soldiers are likely to remain militarily effective during a period of partial sleep loss following a period with no scheduled sleep

at all. To this end, 10 infantry soldiers were scheduled for 4 h of sleep in every 24 for a 6-day period following a 3.75-days period without any scheduled sleep. Performance, physical fitness, and mood were assessed throughout both exercises. Results indicated that the effects of sleep loss are psychological rather than physiological; soldiers are likely to be militarily ineffective after 48-72 h without sleep; and a small amount of recovery sleep relative to the amount lost has very beneficial effects.

162. Haslam D. R. (1985 a). Sleep deprivation and naps. <u>Behavior Research Methods, Instruments & Computers</u>, <u>17</u>, (1), 46-54.

It is important for military commanders to know, under conditions of sustained operations, the likely effects of a small amount of sleep. To this end, 2 laboratory-based, experiments on naps were carried out. The first examined the effect of 2 hours sleep following 90 hours of wakefulness. 10 Infantrymen subjects were not told the scheduled length of their vigil nor that they would soon be allowed a nap until a few hours before the 2-hour sleep. After 3 nights without sleep, average cognitive performance was 55% of the control values. During a test session immediately before the 2-hour sleep, performance improved by 30%, to 85% of control values, indicating the considerable effect that the incentive of knowing a nap is imminent can have on even severely sleep-deprived subjects.

In the second experiment, 2 groups of 6 infantrymen took part in a 5-day trial; one group was scheduled 4 hours uninterrupted sleep, and the other 4 one-hour naps in each 24-hour period.

The results were: (1) no significant difference in cognitive test scores or mood between the 2 groups; and (2) on the last experimental day cognitive test and mood scores were not significantly worse than baseline values for either group. This indicating the utility of 4 hours sleep, either in an uninterrupted block, or scheduled in 4 one-hour naps per day.

163. Haslam D. R. (1985 b). Sustained operations and military performance. <u>Behavior Research Methods, Instruments & Computers</u>, <u>17</u>, (1), 90-95.

A military realistic schedule is one which demands several days with only very limited opportunities for sleep, followed by several days without any opportunity for sleep. A trial was carried out to study the effects of total sleep deprivation following partial sleep deprivation, a previously unstudied

sleep regime. Twelve infantry soldiers, divided into 2 groups of 6, took part in a 6-day trial in which the experimental group was scheduled to have 1 1/2 hours sleep in every 24 hours for 3 days followed by 3 days with no sleep scheduled. The other group, the "control" group, was scheduled for 4 hours sleep in every 24 hours for 6 days. Following the sleep deprivation period, unlimited sleep was permitted for both groups in a 40.25-hour (1.7-day) rest period.

Three of the 6 subjects in the experimental group completed the 152-hour (6.3-day) trial, compared with all 6 in the control group. On the last sleep deprivation day, cognitive performance was 37% of baseline values for the experimental group and 94% for the control group. The results are compared with those for earlier experiments when total sleep deprivation followed a period in which no sleep deprivation was scheduled.

164. Haslam D.R., Allnutt M.F., Worsley D.E., Dunn D., Abraham P., Few J., Labuc S. & Lawrence D.J. (1977). The effect of continuous operations upon the military performance of the infantryman (Exercise "Early Call"). (APRE Report No. 2-77). Farnborough, Hampshire, United Kingdom: Army Personnel Research Establishment.

A 9-day tactical defensive exercise was carried out in order to assess and compare the performance of three platoons of infantry scheduled 0 hours, 1.5 hrs and 3 hrs sleep in every 24 hrs. Experienced military observers judged the platoon with no scheduled sleep remained effective for mainly physical tasks for 3 days: the "survivors" (48%) of the 1.5 hrs sleep platoon, for 6 days; and the "survivors" (91%) of the 3-hrs sleep platoon for 9 days, the duration of the trial. This platoon could probably have kept going for several more days.

The main effect of sleep deprivation was psychological rather than physical: mental ability and mood deteriorated, whereas bodily mechanisms coped adequately. Vigilance and the more difficult and detailed mental tasks deteriorated most, whereas simple and well-learned tasks suffered little. The hostile climate interacted with sleep loss and influenced survival times. After 3 days of rest, assessments indicated that soldiers had returned to their previous levels of performance.

165. Hauty G. T., & Adams T. (1965). Phase shifts of the human circadian system and performance deficit during the periods of transition: I, East-West flight. (FAA Report No. AM 65-28). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Research Institute. (DTIC No. AD 639-637).

At periodic intervals throughout the biological day, biomedical assessments were made for a week prior to jet flight to Manilla, for 8 days of layover at Manila, and for a week following return. The rapid translocation effected primary phase shifts as follows: for rectal temperature and heart rate, 4 days; for palmar evaporative water loss, 8 days. The return flight effected a 1-day phase shift. Behavioral integrity was degraded, although to a lesser extent after return. Duration of behavioral impairment was much shorter than the lag time of physiological phase shifts.

166. Hauty G.T., & Adams, T. (1965). Phase shifts of the human circadian system and performance deficit during the periods of transition: II, West-East flight. (FAA Report No. AM-65-29). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Research Institute.

At periodic intervals throughout the biological day, biomedical assessments were made for a week prior to jet flight to Rome, for 12 days in Rome, and for a week following return to Oklahoma City. A primary shift of circadian periodicity was manifested by physiological functions -- rectal temperature, heart rate, etc. Increase in fatigue occurred during the primary period of transition and following return, but psychological performance was not impaired during either period. Duration of the fatigue was shorter than the time lag of the physiological phase shifts.

157. Hauty G. T., & Adams T. (1965). Phase shifts of the human circadian system and performance deficit during the periods of transition: III. North-South flight. (FAA Report No. AM-65-30). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Research Institute. (NTIS Report No. PB-170 826).

At periodic intervals throughout the biological day, biomedical assessments were made for a week prior to jet flight to Santiago, Chile, for 12 days at Santiago, and for a week following return to Washington, D.C. Although previous East-West and West-East flights effected a primary shift of circadian periodicity, as manifested by physiological functions, the North-South flight did not. There was, however, a significant increase of subjective fatigue, as in the other flights. The significant impairment of psychological performance produced by the East-West but not the West-East

flight was not shown by the North-South flight.

168. Hegge F. W. (1982). The future battlefield: human dimensions and implications for doctrine and research. (WRAIR Report No. NP-82-1). Washington, DC: Walter Reed Army Institute of Research.

The anticipated nature of future land combat is analyzed with respect to the resulting demands on soldiers. Aspects of current infantry doctrine, casually-evolved behavior in the field, and human capacity are analyzed with respect to soldier's performance limits. Doctrine and research recommendations aimed at closing the gap between demands and performance limits are made.

169. Hegge F. W. & Tyner, C.F. (1982). Deployment threats to rapid deployment forces. (WRAIR Report No. NP-82-2). Washington, DC: Walter Reed Army Institute of Research. (DTIC No. AD A131-299).

The multiple sources of stress imposed on troops and commanders involved in rapid, long-range aerial deployment are described. The potential impact of these stresses on combat readiness is discussed. A series of recommendations for measures to prevent these stresses is offered.

170. Heimstra N. W. (1970). The effect of "stress fatigue" on performance in a simulated driving situation. Ergonomics, 13(2), 209-218.

Fifty-four male subjects were assigned to three equal groups and tested in a simulated driving device. The following measures were obtained for each subject: (a) tracking error, (b) speed maintenance, (c) reaction time, and (d) vigilance. In the contingent shock group (stress group) subjects received an electrical shock when errors were committed on one of the tasks. In the second group subjects received random shock with no relationship between shock and performance. The subjects in the control group received no shock. Test sessions in the device were six hours in duration.

No significant differences were found between groups on tracking performance. However, significant differences existed between hours with the contingent shock group showing significantly more tracking error during the last two hours of the test session than during the earlier hours.

On the subsidiary tasks, there were no significant differences between groups on reaction time. However, differences between trials were found with subjects in the contingent group showing significantly slower reaction time

during the last two hours of the session. On the meter vigilance task, subjects in the contingent group missed significantly more signals than subjects in the other groups. Also, on the speed maintenance task the error level for the contingent group was much higher than that shown by the other groups.

Results are discussed in terms of Crawford's (1961) concept of stress fatigue. Findings support the concept that stress brings about an emotional arousal which may interfere with performance on tasks such as driving.

171. Heimstra N. W., Jones H.V., DeKock A. R. (1965). The effects of 'stress fatigue' on performance in a driving device. (USD Report No. TR-4). Vermillion, SD: University of South Dakota Driver Behavior Lab.

Fifty-four male subjects were randomly divided into three equal groups and tested in a simulated driving device. Measures obtained for each subject were: (a) tracking error, (b) speed maintenance, (c) reaction time, and (d) vigilance. In a contingent shock group, subjects received an electrical shock based on their performance on various tasks. In the second group, subjects received random shock with no relationship between shock and performance. The third group, the control group, received no shock.

Test sessions in the device were 6 hours in duration. In the tracking task no significant differences were found between groups; however, analysis of variance showed a significant difference existed between trials. Reaction time was significantly higher in the contingent group during the last 2 hours than during the second, third, and fourth hour. During hours four, five, and six, significantly more signals on the meter vigilance task were missed by subjects in the contingent shock group than in the random shock or control groups. Significant differences existed between speed maintenance scores of the contingent shock group and the other two groups during the fifth and sixth hour of the session. Findings in this study support the idea that stress brings about an emotional arousal which may interfere with performance on tasks such as driving.

172. Heslegrave R.J. & Angus R.G. (1983). Sleep and continuous cognitive work. In: Proceedings of the 24th Defense Research Group Seminar. The human as a limiting element in military systems. (DRG Report No. DS-A-DR-83-170). Toronto, Ontario, Canada: NATO Defense Research Group.

Subjects were required to perform continuous cognitive work in an environment modelled after a command post during sustained battle. They assumed the role of operations duty officers and were required to handle message traffic during a 54-hour period of wakefulness.. Performance was evaluated by monitoring the subjects' message-processing ability and by other objective tests embedded in and interspersed around the messages.

Data are presented to show that sleep loss and sustained mental work can have dramatic effects on cognitive functions, even during the first night of sleep loss. The data also revealed that under this continuous cognitive workload, performance systematically declined. After 18 hours, performance declined substantially and remained at this lower level for approximately another 24 hours. Performance then declined again to a level that would generally be viewed as unacceptable.

173. Higgins E. A., Chiles W. D., McKenzie J. M., Funkhouser G. E., Burr M. J., Jennings A. E., & Vaughn, J. A. (1976). Physiological, biochemical and multiple-task-performance responses to different alterations of the wake-sleep cycle. (FAA Report No. AM-76-11). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Institute.

Three groups, each comprising five healthy, male, paid volunteers (ages 21 to 30), were studied for 11 days. Baseline data were collected for 3 days, during which subjects adhered to a day/night routine, i.e., sleeping from 2230 to 0600. On the fourth day each group took a "flight" in the altitude chamber. Following the flight day, subjects in Group I slept from only 2230 to 0600 and then returned to the baseline routine; subjects in Group II had their day extended by 6 hours and began a new routine of sleeping from 0430 to 1200 for the remainder of the study; subjects in Group III had their day compressed by 6 hours and slept from 2030 to 2400 only that fourth night and then began a new routine of sleeping from 1630 to 2400 for the final 7 days of the study.

According to the physiological and biochemical measurements, there was little difference between the two 6-hour-change groups (Groups II and III), both of which required longer rephasal times than did the group that experienced sleep loss but no time change (Group I). The psychomotor performance test indicated the greatest change in the group whose day was

shortened by 6 hours (Group III). The Multiple Task Performance Battery (MTPB) indicated the greatest deficit in performance for Group III and the best postshift performance for Group II.

Therefore, if performance of the type represented by the MTPB is the most important consideration, then travel from west to east (or "quick turn-arounds" for shift workers) appears to be more deletrious than changes in the opposite direction. However, this effect cannot be predicted on the basis of the physiological and biochemical determinations made in this study.

174. Higgins E. A., Chiles W. D., McKenzie J. M., Iampietro P. F., Winget C. M., Funkhouser G. E., Burr M. J., Vaughan, J. A., & Jennings, A. E. (1975). The effects of a 12-hour shift in the wake-sleep cycle on physiological and biochemical responses and on multiple task performance. (FAA Report No. AM-75-10). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Institute.

Fifteen male paid volunteers (ages 20 to 28) were studied in three groups of five each. The first 4 days of the experiment they slept nights (2230 to 0600) and worked days. On the fifth night, they slept only 3 hours (2100 to 2400) before starting a 10-day period in which the total quantity and quality of sleep did not change significantly when the cycle was altered. According to the subjective fatigue index, the total fatigue for the awake periods was not signifcantly changed; however, the times within days for greatest fatigue were altered and 9 days were required for a complete reversal of the daily pattern. Of the physiological parameters measured, those making the most rapid response to stress rephased in the shortest period of time after the shift. From shortest to longest mean rephasal times, these were: heart rate, nor-epinephrine, epinephrine, potassium, sodium, internal body temperature, and 17-ketosteroid steroids.

Performance data based on the Civil Aeromedical Institute Multiple Task Performance Battery suggest: (1) There was diurnal variation during the preshift period. (2) There were decrements on the day of the shift following the short sleep period. (3) Performance during the first 3 days following the shift was relatively high for most of the day but was relatively poor in the final session of the day. (4) Performance on the fourth through sixth portshift day was average or above for the experiment with relatively small variations among the five test sessions per day. (5) Performance on the seventh through ninth postshift day was below average for the experiment and showed some evidence of a return to a diurnal cycling pattern with a new peak period of

performance that reflected the 12-hour shift in the wake-sleep schedule.

175. Hill A. B., & Williams G. O. (1979). An investigation of landing accidents in relation to fatigue. In E. J. Dearnaley, & P. B. Warr (Eds.), Aircrew stress in wartime operations. (pp. 89-108). London: Academic Press.

In this 1943 work, landing accident rates after sorties of different durations, from roughly 1 hour to 10 hours, were calculated for Bomber Command aircraft returning from operational sorties from April 1940 to March 1942, (excluding accidents due to forced landings or attributed to the results of enemy action).

A detailed analysis of the data by duration of sorties indicated a rather high accident rate for very short sorties of under 2 hours and for very long sorties of 10 hours or more is held to be due, at least in part, to the fact that such short sorties include a number in which the aircraft returned or was recalled owing to some special difficulties (bad weather, technical failure, etc.), which would naturally add to the risks of landing. In the latter, fatigue of the pilot may have been a contributory factor. On the other hand over the relatively long period of time, 2 to 10 hours, which includes the vast majority of sorties made, there is no evidence that increasing fatigue in the pilot led to any increase in the landing accident rate. Within the range of sorties usually flown at this period, it seems that pilots have been able to overcome the fatigue consequent upon long sorties sufficiently, at least, to avert its effects as measured by reportable accidents on landing.

176. Hockey G. R. J., & Colquhoun W. P. (1972). Diurnal variation in human performance: A review. In W. P. Colquhoun (Ed.), Aspects of Human Efficiency (pp. 1-25). London, England: The English Universities Press Ltd.

This paper attempted a coverage of the findings on human performance as a function of time of day. A number of fairly clear conclusions can be drawn from these findings: (1) There is a marked rhythm in the efficiency of human performance, both in normal and in many unusual environmental conditions. (2) This rhythm has a primary period of 24 hours, and its effects appear not only when tests are made during the normal waking day, but also when they are carried out through the night. (3) There is a high degree of correspondence between diurnal changes in performance and in body temperature. (4) Adaptation of the temperature rhythm normally occurs within 4-6 days of a changed sleep-waking schedule, usually in the form of a flattening, rather than a phase-shift, and performance tends to

follow this adaptation. (5) Task selection is an important aspect of design in diurnal rhythm experimentation, since those tasks with a large memory requirement may give an inverted rhythm. (6) Diurnal variation in performance may be minimized by appropriate instruction of, or special "effort" on the part of, the subjects employed; and can be masked by the use of an insensitive test of performance. (7) Care must be taken to eliminate or balance all the known major sources of experimental interference in diurnal rhythm studies if the results are to be of real value.

177. Hoddes E., Zarcone V., Smythe H., Phillips R., & Dement W. C. (1973). Quantification of sleepiness: A new approach. Psychophysiology, 10(4), 431-436.

The Stanford Sleepiness Scale (SSS) is a self-rating scale which is used to quantify progressive steps in sleepiness. The present study investigated whether the SSS cross validates with performance on mental tasks and whether the SSS demonstrates changes in sleepiness with sleep loss. Five college student Ss were given a brief test of memory and the Wilkinson Addition Test in 2 test sessions and the Wilkinson Vigilance Test in 2 other sessions spaced throughout a 16-hr day for 6 days. Ss made SSS ratings every 15 min during their waking activities. On night 4, Ss underwent all night sleep deprivation. On all other nights, Ss were allowed only 8 hrs in bed. Mean SSS ratings correlated $r=.68$ with performance on the Wilkinson Tests. Discrete SSS ratings correlated $r=.47$ with performance on the memory test. Moreover, mean baseline SSS ratings were found to be significantly lower than corresponding ratings of the deprivation period.

178. Hodge D. C. (1972). Military requirements for research on continuous operations. (USAHEL Report No. TM-12-72). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

The Center of Biotechnology and Human Performance at Texas Tech University conducted a research program titled "Performance, Recovery and Man-Machine Effectiveness." The program's goals included investigation of task, environmental and nutritional variables affecting man's ability to perform for long periods of time, as well as factors influencing recovery from the effects of long-term performance.

The Army is considering the feasibility of sustained and continuous operations. Recent technological innovations have rendered this continuous operations notion feasible from a technical standpoint; the question remains open as to whether man is equal to the task.

This conference brought together representatives of the

Defense community and contractors presently performing research related to continuous operations, for the purpose of discussing the concept and attempting to formulate goals and/or gaps in our knowledge of long-term performance and recovery. This report contains the formal presentations to the conference, as well as the edited transcript of discussions following each presentation.

179. Holley D. C., Winger C. M., Deroshia C. W., & Heinold M. P. (1981). Effects of circadian rhythm phase alteration on physiological and psychological variables: Implications to pilot performance (Including a partially annotated bibliography). (NASA Report No. TM-81-277). Moffett Field, CA: National Aeronautics and Space Administration, Ames Research Center.

The effects of environmental synchronizers upon circadian rhythmic stability in man and the deleterious alterations in performance which result from changes in this stability are points of interest in a review of selected literature published between 1972 and 1980. A total of 2,084 references relevant to pilot performance and circadian phase alteration are cited and arranged in the following categories: (1) human performance, with focus on the effects of sleep loss or disturbance and fatigue; (2) phase shift in which ground based light/dark alteration and transmeridian flight studies are discussed; (3) shiftwork; (4) internal desynchronization which includes the effect of environmental factors on rhythmic stability, and of rhythm disturbances on sleep and psychopathology; (5) chronotherapy, the application of methods to ameliorate desynchronization symptomatology; and (6) biorhythm theory, in which the birthdate based biorhythm method for predicting aircraft accident susceptability is critically analyzed. Annotations are provided for most citations.

180. Hord D. J. (1982). An EEG predictor of performance decrement in a vigilance task. (NHRC Report No. 82-2). San Diego, CA: US Naval Health Research Center.

Ten subjects took part in a monitoring task in which alpha numeric symbols were discriminated on 1100 trials during continuous 3-hr "watches". Each subject completed a 3-hr watch on 3 consecutive days. The reaction times for all trials on day 2 and day 3 were divided into the 10 percent fastest, 10 percent slowest, and the errors of omission (EO) for each session. Brain activity at the vertex (Cz) was derived from the one-second period preceding each trial. Ensemble spectral analysis was completed for each subject to yield intensity (microvolts2/Hz) at integral values of frequency from 1 to 20 Hz. It was found that the ratio of slow (1-6 Hz) activity to intermediate (7-12 Hz) EEG activity at the vertex can

differentiate EO from fast and slow trials thus supporting the contention that brain activity recorded at the scalp can be used to monitor vigilance level in rested subjects. The technique could be used to monitor vigilance states in operational settings.

181. Hord D. J., Tracy M. L., Lubin A., & Johnson L. C. (1975). Effect of self-enhanced EEG Alpha on performance and mood after two nights of sleep loss. Psychophysiology, 12(5), and (NHRC Report No. 75-2). San Diego, CA: US Naval Health Research Center.

Can the deleterious effects of acute sleep loss on performance and mood be ameliorated by self-enhanced alpha activity? Fourteen Naval volunteers were divided equally into an experimental (alphacontingent auditory feedback) group and a yoked control (pseudofeedback) group. All subjects received feedback plus performance and mood tests during 3 baseline days and following 2 days and 2 nights without sleep. Feedback was given for 45 min in the morning and 45 min in the afternoon, preceding performance and mood tests.

The self-enhanced alpha (experimental) subjects did produce more alpha than the yoked controls during all feedback sessions except for one pair that was discarded. Of eleven measures that were sensitive to sleep loss, two performance scores and one mood score showed significantly less sleep-loss decrement for the self-enhanced alpha group (at the usual univariate .05 level). Two recall scores and an anxiety score showed more impairment for the self-enhanced alpha group following sleep loss. However, by the conservative Dunn-Bonferroni multivariate criterion, the differences were not significant; so these results are not conclusive.

Alpha enhancement may help maintain performance that requires continuous attention, such as counting and auditory discrimination, but does not ameliorate the sleep-loss effect for anxiety, memory, and addition.

182. Innes L. G. (1970). A subjective assessment of fatigue in transport aircrew. In A. J. Benson (Ed.), Rest and activity cycles for the maintenance of efficiency of personnel concerned with military flight operations: Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Oslo, Norway. (NATO/AGARD Report No. CP-74-70). London: Technical Editing and Reproduction Ltd.

Two questionnaire studies were carried out on fatigue reactions of transport aircrew on transatlantic flights of approximately 12 hours duration. The first questionnaire assessed exhaustion fatigue due to the flight for all crew positions, and identified crewmembers having unusually high ratings. The second questionnaire study assessed nervous fatigue in the same type of operation; two crew positions only were identified as being of concern. There was no relationship between fatigue ratings and sleep patterns, nor with easterly or westerly direction of flight. Analysis of the use of questionnaire items showed that frequency of check marks against "fatigue" statements did not correspond well with fatigue rating.

183. Innes L. G. (1970). Exhaustion fatigue in long range aircraft crews. (Technical Report No. 70-RD-1). Toronto, Ontario: Canadian Armed Forces Institute of Environmental Medicine.

A questionnaire study of fatigue reactions was carried out on transport aircrew on transatlantic flights in both the Yukon and Hercules aircraft. Questionnaire items were designed to assess physical tiredness aspects of subjective fatigue, and assessments were made before every flight, halfway through the flight and after landing. The average ratings for the crews showed an increase in fatigue feelings consistently through the fight, but the positions showing the strongest reaction were the Hercules Navigator and Flight Engineers. Loadmasters on both aircraft showed quite a high degree of subjective exhaustion fatigue. No relationship could be shown between self-rating on the questionnaire and sleep patterns, nor was there a relationship between unusually high or low ratings and eastbound flights.

J

184. Jackson K. F. (1956). Aircrew fatigue in long-range maritime reconnaisance-pilot performance. (FPRC Report No. 907-2). Farnborough, England: Royal Air Force Institute of Aviation Medicine, Farnborough Personnel Research Center.

The performance of ten pilots was investigated by making continuous records of the altitude and heading of their aircraft at chosen times during a series in which each pilot undertook four 15-hour flights. The records, which concerned straight and level flying only, were examined--a 10-minute section at a time--for both extent and variability of error, thus providing four measures for each 10-minute record. Turbulence was recorded in terms of vertical accelerations, and certain personal factors were also observed. Performance in maintaining a constant heading deteriorated during 40 minutes of continuous work. Performance in both heading and altitude deteriorated during the first three of pilots' watches and partially recovered in the fourth.

In their first two watches, pilots tended to fly more accurately and consistently in rough air than in calm air, but in the last two watches they were adversely affected by turbulent conditions. Performance did not change appreciably from flight to flight during a week in which four 15-hour flights were made on alternate nights. The deteriorations which were observed could not be accounted for by increased turbulence.

185. Johnson L. C. (1967). Sleep and sleep loss--their effect on performance. (NMNRU Report No. 67-12). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit.

A brief introduction to the field of sleep research and summary of the material presented at a conference held May 1966 on sleep loss and the recuperative effects of the stages of sleep.

186. Johnson, L.C. (1968). Psychological and physiological changes following total sleep deprivation. Sleep: Physiology & pathology. (NHRC Report No. 68-18). San Diego, CA: US Naval Health Research Center.

A review of the literature on effects of total sleep deprivation. Cognitive and motor tasks of long duration, of low subject interest and witout knowledge of results are highly susceptible to the effects of sleep loss. While marked behavioral and personality changes may occur during prolonged sleep loss (after 150 hours), these changes are usually transient and disappear with sleep in subjects who were emotionally stable before onset of sleep loss. Sleep loss per se does not appear to always result in chronic psychotic behavior. Reports of chemical and physiological changes were inconsistent and no clear cut pattern of change has been found.

187. Johnson L. C. (1973). The effect of total, partial, and stage sleep deprivation on EEG patterns and performance: Behavior and brain electrical activity. (NHRC Report No. 74-11). San Diego, CA: US Naval Health Research Center.

This paper reviews EEG and performance changes following total, partial, and stage sleep deprivation. Most attention is directed toward recent studies concerned with partial sleep loss and sleep stage deprivation.

188. Johnson L. C. (1974). Sleep loss and sleep deprivation as an operational problem. (NHRC Report No. 74-45). San Diego, CA: US Naval Health Research Center. (DTIC No. AD A015-640).

Sleep loss and sleep stage deprivation are reviewed with particular attention to performance decrement and operational consequences. Within the 36-48 hour range of total sleep loss most likely to be experienced by aircrew personnel, no consistent or uniform performance decrement has been found in operational studies even though laboratory studies have found decrement on certain types of tasks, but marked increase in fatigue is a common problem. Sleep loss, both total and partial, tends to potentiate the circadian influence on performance and interact with other stressors to enhance the stress-induced physiological responses. Deprivation of sleep stage REM or sleep stage 4 produces no behavioral changes of operational consequence.

189. Johnson L. C. (1977). The mysteries of sleep. (NHRC Report No. 77-4). San Diego, CA: US Naval Health Research Center.

This article reviews research done by the NHRC Psychophysiology Division concerned with sleep quality, sleep

reduction, and total sleep loss. The description of the work is in a style appropriate for sailors and officers without prior knowledge of sleep research.

190. Johnson L. C. (1979). Sleep disturbance and performance. (NHRC Report No. 79-19). San Diego, CA: US Naval Health Research Center.

While the type of sleep obtained does not appear to be an important factor in performance, the time of day the sleep is obtained and when the performance occurs are very important. Time-of-day effects may be a more crucial factor in performance than the preceding sleep patterns. While the effect of total sleep loss becomes pronounced after 48 to 60 hours, consistent performance decrement following reduced sleep or fragmented sleep has not been found. Feelings of fatigue, however, are a consistent finding in all sleep-loss studies. A significant relation between sleep quality (good vs. poor sleep) and performance is not easily found. The deleterious effect of hypersomnia, especially that due to narcolepsy, has been documented.

191. Johnson, L.C. (1981). On varying work/sleep schedules: Issues and perspectives as seen by a sleep researcher. In: L.C. Johnson, D.I. Tepas, W.P. Colquhoun & M.J. Colligan (Eds.). The twenty-four hour workday: Proceedings of a symposium on variations in work-sleep schedules. (DHHS-NIOSH Report No. 81-127, pp 403-418). Cincinnati, OH: Department of Health and Human Services, National Institute for Occupational Safety and Health.

For sleep researchers the issues of shift work are inadequate sleep, poor sleep quality and fatigue. The author addresses the questions of what is the relationship of sleep per se to the complaints of shift workers? Is the reduced amount of sleep they obtain the cause of their fatigue; is the quality of their sleep inferior; is there a chronic sleep deficit? Is sleep the focus of general dissatisfaction with the work schedule and interacting with social factors? The author reviews the research concerned with sleep quality, sleep quantity and the fragmentation of sleep to see if these factors can account for shift workers' sleep complaints and feelings of fatigue.

192. Johnson L. C. (1982). Sleep deprivation and performance. (NHRC Report No. 80-21). San Diego, CA: US Naval Health Research Center.

This article reviews the background and major theoretical positions that have evolved in sleep deprivation research. It emphasizes the paradoxical nature of performance measures in

this area, the certainty of decrements and the paradoxes of their ephemeral nature. This is followed by a presentation of the wide range of factors which significantly modify the degree of response decrements under conditions of sleep deprivation: fatigue, task variables, and non-task factors; psychological, situational, and behavioral periodicity. Performance variations associated with partial sleep loss and results of experiments, emphasizing continuous performance are described.

193. Johnson L. C., & Naitoh P. (1974). The operational consequences of sleep deprivation and sleep deficit. (NATO/AGARD AGARDograph No. 193, pp. 1-43). London: Technical Editing and Reproduction, Ltd.

Effects of total sleep loss, partial sleep loss, and sleep stage deprivation are reviewed with particular attention to performance decrement and operational consequences. Within the 36-43 hour range of total sleep loss most likely to be experienced by aircrew personnel, no consistent or uniform performance decrement has been found in operational studies even though laboratory studies have found decrement on certain types of tasks. Of major importance are the type of task, the setting in which the task is to be performed, and the individual. Physiological changes are minimal during moderate sleep loss, but mood changes are clearly noticeable.

The most likely sleep problems for aircrew members are those associated with disruption of sleep-wakefulness cycles and partial sleep loss. Consistent performance decrement is difficult to find, but marked increase in fatigue is a common problem. Sleep loss, both total and partial, tends to potentiate the circadian influence on performance and interact with other stressors to enhance the stress-induced physiological responses. Deprivation of sleep stage or sleep stage 4 produces no behavioral changes supportive of earlier beliefs that these two stages, especially stage REM, were necessary for effective waking behavior.

194. Johnson L. C., Naitoh P., Lubin A., & Moses J.O. (1970). Sleep stages and performance. (NMNRU Report No. 71-4). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit.

The relation of sleep stages to performance is reviewed. Data are presented from 12 subjects who were deprived of sleep for two nights to study the recuperative effects of slow-wave sleep and REM sleep following sleep deprivation. There was no significant difference in waking behavior and performance in those subjects denied REM sleep or slow-wake sleep from those subjects allowed all stages of sleep on recovery nights after total sleep loss. The significance of stages of sleep to waking behavior is not yet clear.

195. Johnson L. C., Naitoh P., Moses J., & Lubin A. (1973). Interaction of REM deprivation and stage 4 deprivation with total sleep loss: Experiment 2. Psychophysiology, 11(2), and (NMNRU Report No. 7322). San Diego, CA: US Naval Medical Neuropsychiatric Research Unit.

To determine whether prior deprivation of stage REM or stage 4 sleep would potentiate the effects of total sleep loss, 7 young adult males were denied REM sleep and 7 were denied stage 4 sleep for three nights before one night of total sleep loss. Measures of autonomic and EEG activity, mood, anxiety, Rorschach CET and on several performance tasks were obtained during baseline, following stage deprivation, total sleep loss and during recovery.

There were no marked changes in any area following three nights of stage REM and stage 4 deprivation. The changes following total sleep loss were similar for both groups. Prior deprivation of stage REM or stage 4 did not potentiate sleep loss effects. Ss who had no stage deprivation prior to 1 night of sleep loss had more impairment following sleep loss than did the Ss of this study.

196. Johnson L. C., Naitoh P., Moses M., & Lubin A. (1977). Variations in sleep schedules. Waking and Sleeping, 1, 133-137, and (NHRC Report No. 77-1). San Diego, CA: US Naval Health Research Center.

Our sleep research has explored the effect of total sleep loss, sleep stage deprivation, gradual sleep reduction, and the effect of varying the sleep/wake schedule. While subjects are unable to function effectively without sleep, the type of sleep obtained is not as important as the amount. If done gradually, habitual sleep time can be reduced by 1 to 2 hours and sleep can be obtained in 1-hour segments without significant impairment in performance or mood. When sleep is reduced gradually or by napping, stages 2 and REM are reduced while slow-wave sleep remains the same or increases. Naps are more deleterious for time in stage REM than is gradual sleep reduction.

197. Johnson L. C., Williams H. L., & Stern J. A. (1972). Motivation, cognition, and sleep-work factor: Central and autonomic nervous system indices. (NMNRU Report No. 72-13). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit.

Possible problems for human performance in relation to three factors: motivation, cognition. and sleep, are discussed. Of particular concern are possible alterations in cycles of sleeping and waking, and in physiological patterns of

sleep and the potential effects of such changes on vigilance, memory problem solving, and motivation. An attempt is also made to anticipate the effects of prolonged space-flights on the central and autonomic nervous systems.

198. Johnson L. F. (1967). Sleep requirements during manned space flight. In H. L. Roxburgh (Ed.), Behavioral problems in aerospace medicine. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting, October, 1967. (NATO/AGARD Report No.CP-25). London, Englund: Technical Editing and Reproduction Ltd.

In planning bioastronautics support for manned space flight, thought must be given to the human needs of the astronauts in outer space. A survey of research literature on this subject indicates that consideration must be given to the quality as well as the quantity of sleep. The conclusion of this survey indicates that: (1) If possible, astronauts on prolonged space flights should have 8 hours of continuous sleep, at the normal depth of sleep, out of each 24 hours.
(2) If this is not operationally practicable, a different wakefulness/rest ratio must be used, for example, 12 hours work/6 hours rest plus another 2 hours rest period in each 24 hour period. (3) Further experimental work is necessary to study the quality or depth of sleep as affected by differential cycling of the 24 hour time period.

199. Johnson P. C., Carpentier W. R., Driscoll T. B., La Pinta C. K., Rummel J. A., & Sawin C. F. (1972). Passenger fluid volumes measured before and after a prolonged commercial jet flight. Aerospace Medicine, 43, 6-7.

Interstitial and intracellular fluid volumes were calculated from measured plasma volume, extracellular volume and total body water of six subjects before and after a 24-hour commercial overseas flight. No change occurred in these spaces or in peripheral hematocrit or total serum protein concentration. The subjective feeling of dehydration found among passengers at the end of a long trip of this type seems to represent a shift in body fluids to the dependent portions of the body rather than water retention or a decrease in the intravascular water volume.

200. Jones G. M. (1971). Some aviation medical aspects of flight crew fatigue. (DRB Technical Report No. DR-208 Vol. I, pp.1964-1968). Ottawa, Canada: Department of National Defense, Defense Research Board.

This review article attempts to outline some of the negative effects of fatigue in flight crew personnel for researchers, aircraft designers, and legislators. Stressors

associated with instrument flight and their effect on the pilot's vestibular system are examined in depth. Fatigue is also defined and the need for obejctive, as opposed to subjective, measurement of its effects on performance are discussed. A description of the "Cambridge Cockpit Experiments," conducted by D. R. Davis during WW II, and a summary of the conclusions based on those experiments, are presented. The author discusses the need for new legislation, based on scientific study, to help control flight crew fatigue problems.

K

201. Kanabrocki E. L., Scheving L. E., Halberg F., Brewer R. L., & Bird T. J. (1974). Circadian variation in presumably healthy young soldiers. Chicago, IL: USAR Medical Laboratory. (NTIS No. PB 228-427).

A group of thirteen young soldiers was standardized for approximately 30 hours with rest time extending from 2245 to 0700 h; during their activity time they abstained from any unusual or strenuous activity and ate meals only at 0830, 1430 and 1630. Each man was sampled at three-hour intervals throughout one 24-hour period; this involved the measurement of oral temperature, radial pulse, blood pressure, intraocular pressure and minute ventilation. In addition, a sample of blood and urine was collected at each time point and subsequently a total of 18 biochemical or other measurements on each sample of urine.

One year later another study was performed similarly on twelve men over a 72-hour period. In this instance oral temperature, radial pulse and blood pressure were determined, and, in addition, several psychological and performance tests were made; these include: estimation of mood and vigor, eye-hand coordination, finger counting (a performance test), ability to estimate time, random addition and memory ratio.

All data were analyzed by a computerized inferential statistical method which involved the fitting of a 24-hour and other cosine curves to the data by a method of least squares. A great majority of the many variables analyzed demonstrated a significant fit to a 24-hour cosine curve. From this same analysis, one was able to estimate three rhythmic parameters and their confidence, the amplitude and the mesor (computer-determined over-all mean). The significance of these data is discussed.

202. Kant J. G., Genser S. G., Thorne D. R., Pfalser J. L., & Mougey E. H. (1984). Effects of 72 hour sleep deprivation on urinary cortisol and indices of metabolism. Sleep, 7(2), 142-146.

Cortisol, urea, glucose, electrolytes, and other compounds were measured in five consecutive 24 h urine collections during

a 72 h sleep deprivation study of six young men. Urine was collected during a 24 h predeprivation day, 3 days of sleep deprivation, and a recovery day. Whereas urinary cortisol decreased only slightly, marked changes in other urinary constituents were observed. During sleep deprivation, urinary urea rose markedly, glucose decreased, and urinary electrolytes decreased. These data indicate that sleep deprivation under ad lib food and water conditions can cause disturbances in normal metabolism.

203. Karney D. H., & Thompson P. (1976). Fatigue. US Army Aviation Digest, 22, 28-34.

Fatigue is a significant hazard in Army aviation. It reduces crewmember efficiency and contributes to reduced performance, poor coordination, faulty memory, slower reaction time and a decline in perceptual abilities. Few people actually appreciate the full extent and consequences of the effects of fatigue on aircrew performance. Also, many units fail to establish maximum flight time and crew rest limitations in accordance with Army Regulation 95-1. Crewmembers have to cope with numerous fatigue-producing stresses, such as those imposed by aircraft factors, flight operation factors, duration of work and rest in the duty day, scheduling of work and rest cycles, social, emotional and self-imposed factors and morale.

To determine which factors in the aviation environment have the most bearing on fatigue, a survey of 500 experienced helicopter pilots was conducted by the NATO Advisory Group for Aerospace Research and Development (AGARD). The ratings are listed in the article. Also included in the article is a comparison of actual flying hours/rest period standards in various worldwide military aviation agencies for rotary wing aircraft.

204. Kimball K. A. (1983). Selected factors affecting aircrew performance during sustained operations. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP 338, pp. 20-1 to 20-17). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-990).

Six recent graduates of initial rotary wing training flew a UH-1H utility helicopter for up to 4 hours while wearing each of three clothing ensembles. Each aviator wore the standard flight suit, the US chemical defense (CD) ensemble and the United Kingdom (UK) CD ensemble in hot weather (mean WBGT 29 degrees C). Skin temperatures (chest, thigh, upper arm, and calf), rectal temperature, heart rate, and preflight and

postflight body weights were recorded. Cognitive testing was conducted preflight, postflight, and on non-flight days. Aviator flight control performance measures were also obtained during flight.

Well acclimatized aviators were able to fly at least 2 hours without serious physiological impairment. Three of the six aviators terminated flight for medical reasons (heart rates over 140 bpm or nausea) while wearing the US ensemble. In this study the susceptible subjects tended to be older and heavier. Heart rate was judged to be the most sensitive indicator of heat stress.

Cognitive testing and flight performance data obtained during this exercise did not demonstrate changes as a function of the type of flight ensemble worn during the test, nor did flight performance serve as a predictor of heat stress. Further investigations are required to verify the validity of these measures as indicators of heat loading in the operational setting.

205. Kimball K. A., & Anderson D. B. (1975). Aviator performance: Biochemical, physiological, and psychological assessment of pilots during extended helicopter flight. In H. S. Fuchs, G. Perdriel, & A. Gubernale (Eds.), The role of the clinical laboratory in aerospace medicine. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Ankara, Turkey. (NATO/AGARD Report No. CP-180). London: Technical Editing and Reproduction Ltd.

This investigation was conducted to provide information on the physiological, psychological and performance effects of extended helicopter flight. Measurements of biochemical, physiological and psychological parameters were taken and compared with inflight performance measures obtained by the US Army Aeromedical Research Laboratory Helicopter Inflight Monitoring System. Six rotary wing aviators performed extended daily flight missions for 12 hours per day for a period of five days. In addition, when not flying, various psychological tests were administered. Physiological and biochemical monitoring were conducted throughout the five day period. Subjects were on a controlled diet and slept approximately three hours each night. This paper presents preliminary findings with regard to performance, biochemical, physiological and psychological parameters.

206. Kinsley H. W. (1964). Stress, fatigue, and the general line officer. (NPS Master's thesis). Monterey, CA: Naval Postgraduate School. (DTIC No. AD A481-430/7ST).

Stress and fatigue are important factors in the decision making process. As such they should be of great interest and concern to the Navy, particularly in their relationship to the decision making capabilities of unrestricted line officers. Recent writings and experimentation in stress and fatigue are analyzed to point up the importance of these phenomena as they affect the unrestricted line officer, to examine the methods which the Navy might use in measuring and prediction, and to show applications which might be attempted in the areas of alleviation and control. The destroyer commanding officer is the criterion against which the stress and fatigue are measured.

The conclusions are that fatigue and the effects of stress are, indeed, quite serious in their ramifications, that the Navy should be more cognizant of them, that positive programs can be estabished to reduce these effects at nominal cost, and that such programs might have valuable pay-offs in ships and lives.

207. Kjellberg A. (1977). Sleep deprivation and some aspects of performance. Waking and Sleep, 1, 149-153.

The problem of arousal and arousal changes after sleep deprivation are discussed. Lapses and other attentional effects are described. The problems of motivation and performance in connection with sleep deprivation are reviewed. Conclusions are drawn from the complete set of reference and review material.

208. Klein K. E., & Wegmann H. M. (1979). Circadian rhythms in air operations. NATO Advisory Group for Aerospace Research and Development, Lecture Series. (NATO/AGARD Report No. LS-105). London: Technical Editing and Reproduction Ltd.

After a brief introduction into the principles of environmental and biological timing systems, the phenomenology of post-transmeridian de- and resynchronization of circadian rhythms is presented, its control and modification through external and internal factors described, and the consequences for human efficiency and health discussed. There are conclusions drawn as to possible relief measures, and formulas and models reviewed which try to define the physiological processes and predict work loads occurring in transmeridian flight operations. Finally, the incorporation of circadian rhythm's aspects into Rest/Duty Regulations is described.

209 Klein K. E., & Wegmann H. M. (1980). Significane of circadian rhythms in aerospace operations. (NATO/AGARD Report No. AG-247). NATO Advisory Group for Aerospace R & D. London: Technical Editing and Reproduction, Ltd.

For over a century it has been recognised that the functional state of the human body is subject to periodic daytime-dependant oscillations which are called "Circadian Rhythms". Not only wakefulness and sleep alternate with the environmental light-dark cycle, for it has been established that most physiological and behavioural functions have an oscillatory nature. Certain hours of the 24 hour cycle have been identified as those where the tonic physiologic levels are set for sleep and "readiness for efficiency" is reduced. Though the underlying mechanisms for biologic circadian periodicity are as yet unknown, its relationship with the environment and with controlling endogenous and exogenous factors has become increasingly clear.

Because performance efficiency and health are affected, circadian rhythmicity has become a major concern not only for industrial shift work, but for military operational situations as well. This AGARDograph, together with those previously published on "Operational Aspects of Variations in Alertness" (No. 131) and "The Operational Consequences of Sleep Deprivation and Sleep Deficit" (159), and the lecture Series on "Sleep, Wakefulness and Circadian Rhythm" (232) should present a useful source for planning and managing aerospace operations in harmony with human functional capacity.

210. Klein K. E., Wegmann H. M., & Bruner H. (1968). Circadian rhythm in indices of human performance, physical fitness and stress resistance. Aerospace Medicine, 39, 512-518. (DTIC No. AD 692-748).

In order to estimate the existence and magnitude of rhythmic day-night variations in human performance, physical fitness and stress resistance, the following variables were measured every three hours over a full day-night cycle: reaction time and its individual constancy, the maximal psychomotor coordination ability, the Schneider index, the predicted VO_2 max, the cardiovascular responses to tilting, and the "time of useful consciousness" at simulated altitude. The twenty-four hours were divided into two experimental sessions so that limited sedentary activity could be maintained between the tests.

All parameters (including body temperature, blood eosinophils, plasma-protein, aldolase and 17-OHCS) revealed relative rhythmic oscillations of the circadian type, the ranges of which varied for the group average between 1.4

percent (temperature) and 68 percent (17-OHCS) from the total twenty-four hour average. Negative extreme values were shown during the night hours for all cardiovascular parameters; consequently, the Schneider index and the VO_2 max predicted from the heart rate level during submaximal exercise had their positive peaks or best values at this time of the day. This phenomenon seems to be an "artificial" effect of the method of determining physical fitness and probably is not identical with the course of "fitness" itself. However, "true" positive night peaks were found for the altitude tolerance. The significance of the results for the applicability of functional tests and human efficiency during stress are discussed.

211. Klein K. E., Wegmann H. M., Anthanassenas G., Hohlweck H., & Kuklinski, P. (1976). Air operations and circadian performance rhythms. Aviation, Space, and Environmental Medicine, 47, 221-230.

This paper reviews experimental results and pertinent data from the literature on circadian behavioral rhythms and their modifications through various factors. It relates them to the operation of aircrews "round the clock" and on transmeridian routes and discusses some possibilities of an appropriate scheduling.

212. Kleinhanss G., & Schaad G. (1983). Sustained military operations with particular reference to prolonged exercise. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of NATO Advisory Group for Aerospace R &D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338, pp. 30-1 to 30-9). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-995).

Since about 1979 we have been confronted with the inevitable situation of expecting combat soldiers to engage in sustained military operations on the battlefield. The land-forces of the Warsaw Pact nations have the capability, both in terms of personnel strength and in technological innovations, to fight with undiminished severity around the clock for days, possibly weeks. For want of adequate troop strength, NATO countries have to counterbalance the "Rationalization" of military working-places by use of more sophisticated technical means and by prolonging the duration of missions. One of the consequences is that of temprary partial or total sleep deprivation for their own troops.

In this report, tests on the effects of sleep-deprivation on (military) performance are analyzed critically and alternatives are pointed out for testing questions arising in context with this problem. Especially important coverage is

given to the influence of motivational influences on human performance, something which the authors contend is given much too little attention in most experimental investigations. The authors report their own experimental experience on this aspect of sustained operations and sleep deprivation experiments. They give proposals to provoke motivation of test participants even in peace-time-conditions and discuss the implications for the effects of participant willingness for performance measures.

213. Knapp S. C. (1970). <u>Problems of adaptation to long range large scale aerial troop deployments.</u> (USAARL Report No. 71-10). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

This paper discusses the demonstrated stresses and adaptation problems during large scale, long range, rapid reaction time, aerial troop deployments. NATO Exercise, REFORGER I, January 1969, and other large scale aerial troop deployments are discussed.

Long range aerial troop transport and deployment is a technological achievement of the 1960's that influenced and shaped international political thinking and military strategy. "Super transport aircraft," capable of around-the-world troop lifts, became a reality in the military inventory. Careful consideration must be given to the aircrews that operate these aircraft. It is necessary to carefully assess the position, role, and regard for the individual soldier, the "passanger," whom all of this aviation technology and engineering supports.

Historically, soldiers have proven to be flexible, well-motivated, and capable of great personal and group ingenuity and adaptation in the face of stress. These factors create fighting forces that are able to go almost anywhere, at any time by any means, and remain efficient and effective. Certain human factors and parameters of personal adjustment and adaptation, however, are relatively fixed or slow to change. Among them are requirements for sleep, food, fluids, exercise, warmth, shelter, sensory stimulation, recreation, periods of quiet, and physical and psychological support. Man has proven biological or circadian rhythms that are essentially unalterable over prolonged periods of stress, let alone abrupt exposure. Man does not immediately adapt to sudden enviornmental changes, i.e., sea level to mountainous, arctic to equatorial, tropical to arid, or pastoral to aquatic.

Man's response to these changes or deprivations, until he accommodates, covers a wide physiologic and psychological spectrum. The individual's response from obscure biochemical alterations to physical and mental degradation are understood

to some extent. A good many are predictable and quantifiable. All have the same titratable and point-reduced effectiveness and efficiency.

214. Knauth P., Rutenfranz J., Hermann G., & Poeppl S. (1978). Re-entrainment of body temperature in experimental shift-work studies. <u>Ergonomics</u>, <u>21</u>(10), 775-784.

In a series of experimental shift work studies, six subjects worked on continuous night shift for three weeks, four subjects worked on a 1-1-1 shift system (1st day morning shift, 2nd day afternoon shift, 3rd day night shift, 4th day off), and two subjects worked on a 2-2-2 shift system (the "metropolitan" rota). Rectal temperature was continuously recorded in each experiment.

The greatest changes in the circadian rhythm of body temperature occurred on the second night shift day, and during the first week of continuous night shift working. The changes involved both shifts in the phasing of the rhythm, and alterations in form. The re-entrainment of the rhythm to its normal phasing took two or more days after two or more successive night shifts, but only one day after a single night shift. Considerable individual differences in the rhythm adjustment to night work were observed.

In a field validation of these findings, 34 shiftworkers in municipal gas and water supply jobs measured their oral temperature every 2 h both on and off duty. Although only very few temperature readings were obtained during sleep periods, the results confirmed, in general, those of experimental studies.

215. Kospstein F. F., Siegel A. I., Wilson L. B., & Ozkaptan H. (1979). <u>Human performance in continuous operations: Volume II. Management guide</u>. (USARI Report No. 80-4b). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

Guidelines are presented for the management of human resources relative to maximizing unit effectiveness during continuous operations. Concrete "ground rules" for personnel management are presented vis-a-vis continuous operations. Steps to take prior to actual combat are given along with methods for controlling performance degradation during continuous operations. Projected soldier effectiveness as a function of battle length and type of unit are presented.

216. Kopstein F., Siegel A., Ozkaptan H., Dyer F., Conn J., Slifer, W., & Caviness J. (1982). Soldier performance in continuous operations. (ARI Report) Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

If any Army unit is to meet the demands of continuous operations, a systematic human resources conservation program must be planned and implemented. The details of such a program are described. Without such a program, intolerable levels of performance decrement are projected during continuous operations.

Strategies for countering the anticipated degradation during continuous operations include: leadership training, confidence building, organizing for full communications, behavioral modeling, overtraining, and crosstraining, developing physical fitness, and development supports.

Tactics for countering performance degradation during continuous operations include task rotation, task sharing, use of performance supports, proper management of stress, and appropriate work-rest cycles.

The plan for integrating these concepts into a unit developmental program includes systematic steps along a time frame. The strategies are set in place during the preparatory stage, and these provide the foundation for implementing the tactics during continuous operations.

217. Kramer E. F., Hale H. B., & Williams E. W. (1966). Physiological effects of an 18-hour flight in F-4C aircraft. Aerospace Medicine, 37, 1095-1098.

Physiological assessment was performed by means of post-flight urinalysis for 8 pilots who flew F-4C aircraft for 18 hours. Flight effects were neither numerous nor of large magnitude, nor were the pilots unduly fatigued. The flight-induced, physiological changes included: (1) increased 17-hydroxycorticoid excretion, which implies adrenocortical stimulation, and (2) decreased excretion of uric acid, potassium, and urine, which suggests metabolic depression.

218. Kripke D. F., Fleck P. A., Mullaney D. J., & Levy M. L. (1981). Sleep loss effects on continuous sustained performance: Behavioral analogs of the REM-nonREM cycle. (Department of Psychiatry Report No. 2). La Jolla, CA: Department of Psychiatry, University of California.

About-90-minute cycles in various waking behaviors have been described, including a 90 minute alternation in hemispheric dominance. To confirm this finding, 11 healthy

young subjects were isolated for 10 hours. Letter-matching and spatial dot-matching tasks were administered every 10 minutes, while sleepiness, fantasy, eating, and drinking were also monitored. No about-90-minute cycle in letter-matching, dot-matching, or their ratio was found, but weak evidence appeared for cycles in eating, drinking, and restroom trips.

219. Kripke D. F., Mullaney D. J., & Messin S. (1979). Measuring sleep by wrist actigraph. (Department of Psychiatry Technical Rep. No. 1). La Jolla. CA: Department of Psychiatry, University of California.

Using a piezo-electric transducer, wrist activity was recorded simultaneously with EEG, EOG, and EMG to obtain 102 recordings-- 39 from hospital patients and 63 from non-patients-- during both Sleep and Wakefulness. On a minute-to-minute basis, wrist activity alone was used to estimate Sleep Time. Blind independent scoring of the EEG-EOG-EMG records was also done for Sleep and Wakefulness. Results from the two Sleep/Wake estimations agreed 94.5% of the minutes. Correlations between the two methods were determined for Total Sleep Period (r=0.90), Total Sleep Time (r= 0.89), Total Wake Within Sleep (r=0.70), and number of Mid-Sleep Awakenings (r=0.25).

Correlation coefficients were even higher when the 39 patients were excluded from the computations. On the average, the actigraphic method overestimated Sleep Time by 10 minutes. Continuous wrist activity recordings provide simple, inexpensive, but very accurate estimates of Sleep Time and hold good potential for unobtrusively measuring amounts of work/rest activity and sleep during continuous operations in the field.

220. Kripke D. F., Mullaney D. J., Messin S., & Wyborney V. C. (1978). Wrist actigraphic measures of sleep and rhythms. Electroencephalography and Clinical Neurophysiology, 44, 674-676.

Recently, Kupfer (1972), Foster (1972) and colleagues have described the use of an actigraphic telemetry system for quantifying both sleep and biologic rhythms. They have reported surprisingly high correlations of 0.84 and 0.88, between wrist activity and wakefulness as determined by EEG in separate studies (Kupher et al. 1972; Kupfer and Foster 1973). Encouraged by their results, we have developed a more flexible system and have validated its usefulness in distinguishing sleep and wakefulness. The system is described in this document.

221. Kripke D. F., Webster J. B., Mullaney D. J., Messin S., & Fleck P. (1981). Measuring sleep by wrist actigraph. (Department of Psychiatry Technical Report No. 4). La Jolla, CA: University of California, Department of Psychiatry.

Future warfare may be exceptionally intense and brief, offering personnel little time for sleep. Fatigue could be a crucial factor in combat performance, especially if troops are airlifted across time zones and subjected to jet lag. Therefore, monitoring sleep loss and facilitating adequate sleep are crucial aspects of military medical planning. To monitor sleep in field conditions, a new technology is needed.

People move constantly when awake but little when asleep. Electronic recognition of activity can thus be used to monitor and determine sleep/wake states. This report summarizes the research and development of a wearable sleep monitoring system. Wrist activity is measured with a piezo-ceramic transducer, monitored and stored by a microprocessor, then transferred to a larger computer for automatic sleep scoring.

In prospective validation trials, the automatic measurement of sleep by a prototype device correlated r=0.97 with EEG sleep scoring. Full technical specifications are presented for construction of field-deployable sleep monitors which could be worn entirely on the wrist. Deployment of such devices would permit operational objective measurement of sleep loss among our troops.

222. Krueger G. P., & Fagg J. N. (1981). Aeromedical factors in aviator fatigue, crew work/rest schedules and extended flight operations: An annotated bibliography. (USAARL Report No. 81-1). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

The influence of aviator fatigue on sustained flight operations is an important aeromedical topic. Available research data on the topic are either in short supply or are scattered throughout diverse printed sources and are difficult to tap when questions of their application to operational decisions are posed. This annotated bibliography lists 224 references containing research data, conceptual position papers and different methodological approaches to studying aviator fatigue, aviation crew work-rest schedules and extended flight operations. The bibliography contains an index which categorizes the references into such categories as:
(1) circadian rhythms and jet lag; (2) psychological measurement of performance; (3) helicopter, transport, and civilian flight operations; (4) crew work-rest schedules; and (5) biochemical and physiological indices of fatigue. The basic period of coverage is 1940-1980.

223. Krueger G. P., & Jones Y. F. (1978). U.S. Army aviation fatigue-related accidents, 1971-1977. (USAARL Report No. 79-1). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

An accident data survey was made to determine how frequently aviator crew fatigue may have contributed to US Army Aviation accidents from 1971 to 1977. All accident reports in the US Army Agency for Aviation Safety (USAAVS) data base were reviewed. Aviator fatigue was deemed to be a contributing factor in 42 rotary wing accidents which resulted in a total of 51 fatalities and 63 personnel injuries. Fatigue contributed to 10 fixed wing accidents, resulting in 3 fatalities and 5 injuries. This paper categorizes these fatigue-related accidents by aircraft and mission type and by time of day and day of week of the accident. It also tabulates pilot activities prior to the accidents which promote the likehood of pilot fatigue contributions. The personnel and equipment costs of these accidents to the Army are estimated, and the relative importance of such accidents to the total US Army aviation accident picture is assessed.

224. Krueger G. P., Armstrong R. N., & Cisco R. R. (1980). Aviator performance in week-long extended flight operations in a helicopter simulator. In R. Auffret (Ed.), Session A: Aircrew safety and survivability. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Bodo, Norway, May 1980. (NATO/AGARD Report No. CP-286; pp. A20-1 to A20-13). London: Technical Editing and Reproduction Ltd.

In the second experiment in a series of studies on near continuous operations, psychological, physiological and biochemical correlates of aviator crew performance, stress and fatigue were measured in a week-long flight schedule in a helicopter simulator. Three 2-man crews of rotary wing aviators performed 14 hours of precision instrument flight in a simulator on each of five successive work days. Missions included repetitions of routine 2-hour standardized day and night instrument flight profiles which were occasionally interrupted by simulated flight emergency situations.

Aviator flight performance was measured. Parameters assessed included: meeting airspeed, altitude, headings, turn rates, navigation, etc. In addition, measures of fatigue, stress and bodily state were collected throughout the study. These latter measures included physiological (cardiovascular monitoring and body temperature), psychological (behavioral, short term memory, oculomotor performance and subjective ratings), and biochemical (urine and isoprene) parameters. When not flying, pilots participated in laboratory tests of pursuit rotary tracking skill and visual search strategies. They were also examined by flight surgeons daily. The pilots ate

three regularly scheduled meals and slept approximately four hours each night. Baseline data were collected prior to, and recovery data after the extended flight schedule.

This paper presents a description of the study and summarizes preliminary findings of portions of the data. The findings of this research should be useful to operational flight surgeons, aviation safety officers and unit personnel strength planners.

225 Krueger G. P., Armstrong R. N., & Cisco R. R. (1985). Aviator performance in week-long extended flight operations in a helicopter simulator. Behavior Research Methods, Instruments & Computers, 17, 1, 68-74.

Psychological, physiological and biochemical correlates of aviator crew performance, stress and fatigue were measured in a week-long flight schedule in a helicopter simulator. Three 2-man crews of rotary wing aviators performed 14 h of precision instrument flight on each of four successive days and 10 flight h on the 5th day. Missions involved repetitions of 2-h standardized day and night flight profiles that were occasionally interrupted by simulated emergencies. Aviator performance measures included: meeting assigned airspeeds, altitudes, headings, turn rates and navigation requirements. Pilots slept 4 h each night. Baseline data were collected prior to, and recovery data after the extended flight schedule.

Pilots maintained simulator flight parameters to within acceptable tolerances of assigned headings, airspeed and altitudes even into the morning of the fourth day of the schedule. However, cognitive and judgmental errors were made. Even though flight surgeons deemed them unsafe to fly by the third night, pilots continued to fly well to the fifth day.

L

226. Lavie, P., Gopher, D, Fogel, R., Zommer, J., (1981). Ultradian Rhythms in Perceptual Motor Tasks. In L.C. Johnson, D.I. Tepas, W.P. Colquhoun & Colligan, M.J. (Eds.), The twenty-four hour workday: proceedings of a symposium on variations in work-sleep schedules (pp. 181-195). Cincinnati, OH: National Institute of Occupational Safety and Health, US Department of Health and Human Services.

Research of rhythms in human performance has mostly focused on circadian rhythms (CR), and for obvious reasons: a) there is a large volume of data on circadian rhythms in biological processes, b) there are distinct and measurable circadian environmental "time givers" that can potentially modify behavior, and c) the nature of human engineering problems presented by increases in air travel growth and shift work are related to circadian rhythms. Experimental designs directed toward the investigation of CR tend to obscure short term variation in performance by employing sampling rates too slow to detect rapid variations, and by averaging data across subjects, a procedure which hides time related variability.

The term ultradian rhythms (UR) was introduced by Halberg (1967) to describe rhythms with frequencies greater than 1 per day. In recent years most of the research on UR has been focused on rhythms within the frequency range of 10 to 20 cycles/day, which corresponds to the frequency range of the sleep REM-NONREM cycles. These latter cycles, easily measured during sleep, are suggested to be part of a more general biorhythm that is manifested in wakefulness as recurrent fluctuations in arousal.

This paper reports the results of two experiments investigating UR in two perceptual motor tasks: linear positioning and tracking. Orthogonal variance spectra was used to determine whether significant ultradian rhythms occurred in the data, and subsequently least squares spectra was used to pinpoint the exact periodicity and to estimate its contribution to the total variability.

During the experimental session one group was tested on linear positioning every 10 minutes while another group was

given the task every 20 minutes. Subjects were tested for 10 hrs. from 0800 to 1800. Subjects also performed two dimensional tracking tasks. Each subject was tested every 10 min. for 1.5 min for 12 continuous hours.

Results demonstrate the existence of approximately 100 min UR in both linear positioning and tracking tasks. The presence and magnitude of these rhythms were more pronounced in the linear positioning task. Although it is not necessary to assume separate physiological mechanisms, it appears that the prevalaence and magnitude of the oscillations depend both on the nature of the tasks involved as well as on within task variables.

227. Lees M. A., Kimball K. A., & Stone L. W. (1977). The assessment of rotary wing aviator precision performance during extended helicopter flights. In R. Auffret (Ed.), Studies on pilot workload. Proceedings of the NATO Advisory Groupd for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Koln, Germany. (NATO/AGARD Report No. CP-217). London: Technical Editing and Reproduction Ltd.

To insure the most effective utilization of his aviation resources, the rotary wing flight commander requires information which describes how extended flight time affects the operational capability of his flight crews. In response to this requirement, the US Army Aeromedical Research Laboratory conducted an investigation of man-helicopter system performance during five days of extended flight. This report describes the changes in pilot performance and aircraft stability on one of the maneuvers performed during the large scale fatigue investigation: the stabilized three-foot precision hover. In addition, this report describes changes in subjective ratings of fatigue and flight performance, and changes in the measurement of auditory reaction time.

The results obtained during this examination strongly suggest the occurrance of a learning effect across the first day of extended flight. The most stable hover performance was observed during the second flight day. By the third flight day, pilots attempted to maintain high quality precision hovers through an increase in the number of control inputs. Results obtained on the fourth day of flight suggest that the pilots have shifted their control technique from active control of the helicopter to a more passive strategy of responding to observed error.

Subjective rating scales clearly demonstrate a progressive increase in the rated levels of fatigue between and within flight days. This increase in the level of fatigue corresponds to a general decrease in the ratings of flight performance.

228. Lees M. A., Simmons R. R., Stone L. W., & Kimball K. A. (1973). Changes in the rotary wing aviator's ability to perform an uncommon low altitude rearward hover maneuver as a function of extended flight requirements and aviator fatigue. In S. C. Knapp (Ed.), Operational helicopter aviation medicine. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Fort Rucker, AL April 1978. (NATO/AGARD Report No. CP-225). London: Technical Editing and Reproduction Ltd.

Changes in man-helicopter system performance for a variety of flight maneuvers were examined. The system performance changes in the rearward hover maneuver across five days of an extended flight schedule are described. System performance is categorized into measures of the pilot's control performance, measures of the aircraft's stability, and combined measures of total system performance for each primary aircraft control channel. System performance changes across the five flight days and within the flight days were examined using multivariate analysis. Significant changes in each aircraft control channel are presented and the overall changes in system performance are discussed.

229. Lees M. A., Stone L. W., Jones H. D., Kimball K. A., & Anderson D. B. (1979). The measurement of man-helicopter performance as a function of extended flight requirements and aviator fatigue. (USAARL Report No. 79-12). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

Field commanders have long been concerned about the impact of fatigue on aviator effectiveness, especially where aviators are called upon to fly numerous successive stress-related missions, e.g., combat and/or rescue work. At present there is little specific information upon which the commander can base his crew rest decisions. The US Army Aeromedical Research Laboratory sought to answer this need by observing pilots in an actual flight situation. In this study six pilots flew a helicopter for 11 1/2 hours per day for 5 days with 3.5 hours of sleep per night. Data collection included biochemical, visual, psychological and in-flight measurements. This report includes a critical literature review and describes the methodology of the study It is intended to serve as a detailed background for the analyses to follow.

230. Legg S. J., & Haslam D. R. (1984). Effect of sleep deprivation on self-selected workload. Ergonomics, 27(4), 389-396.

Psychological methods have been used successfully to establish maximal acceptable loads (MALs) in industrial

repetitive lifting tasks, and it is known that physical tasks remain relatively unaffected by sleep deprivation, whereas cognitive tasks may be significantly degraded. Since the psychophysical method is essentially a physical task yet has a cognitive element (in that subjects are required continuously to reassess their decisions reagarding MAL based upon their perceptions of the load weight), it was not known whether MAL would remain unchanged or be degraded by sleep deprivation.

Two groups of soldiers (a sleep-deprived and a control group) were studied over a 3 week period. After 5 training days, a week-end and 2 baseline days, the sleep-deprived group was partially sleep deprived for 3 days and then totally sleep deprived for 2 days, while the control group was allowed 4 hours uninterrupted sleep daily. There followed 1 day during which the subjects were allowed to sleep as they felt necessary, and 2 days of recovery measurements.

There was no significant difference in MAL between the two groups, nor in the pattern of load adjustment adopted by the subjects. It was concluded that the assessment of MAL, using psychophysical methods, is uninfluenced by sleep deprivation.

231. Lindbergh C. A. (1953). Spirit of St. Louis. New York: Charles Scribner & Sons.

This book contains a detailed account of Lindbergh's flight from New York to Paris in 1927. It contains Lindbergh's own graphic description of an aviator's attempt to fight off the onset of fatigue in his historic first transatlantic flight which took 33.5 continuous flight hours. The book also contains the story of his boyhood and youth and his experiences as a pilot of mail planes.

232. Litsov A. N. (1973). Rhythm of sleep and wakefulness in crews of the spaceships Soyuz 3-9 before, during and after exposure to spaceflight. Izvestiya Akademii Nauk SSSR, Seriya Biologicheskaya, No. 6 1972, Moscow.

The report contains data on the work and rest regimes of crew members of the Soyuz 3-9 spaceships in the course of preparations for and implementation of space flight.

233. Lubin A. (1967). Performance under sleep loss and fatigue. (NMNRU Report No. 67-26). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit.

Recent research on the effects of acute sleep loss shows greater effects for longer task duration, greater monotony, greater signal and response uncertainty, and less knowledge of results. It is presumed that cumulative, chronic sleep loss

has similar or more serious effects, and prolonged sleep loss (over 100 hours) may result in psychotic-like states.

234. Lubin A., Hord D., Tracy M. L., & Johnson L. C. (1975). Effects of exercise, bedrest and napping on performance decrement during 40 hours. Psychophysiology, 13(4), and (NHRC Report No. 75-43). San Diego, CA: US Naval Health Research Center.

Young male Naval volunteers were denied normal nocturnal sleep and maintained on a 60-min treatment - 60-min testing schedule for 40 consecutive hours. Ten subjects bicycled, 20 subjects controlled EEG activity during bedrest, and 10 subjects napped. Eight measures of addition, auditory vigilance, mood, and oral temperature were obtained. The Bedrest group showed significant impairment on all eight measures, and thus, gave no support to the forced rest theory of sleep function. The Exercise group was worse than the Nap and Bedrest groups for all measures. In spite of fragmented, reduced sleep (about 3.7 hours per 24 hours), the Nap group had no impairment on six of the measures. The results suggest that exercise increases the impairment due to sleep loss, and naps reduce or remove this impairment. Bedrest is not a substitute for sleep.

235. Lubin A., Moses J., Johnson L. C., & Naitoh P. (1973). The recuperative effects of REM sleep and stage 4 sleep on human performance after complete sleep loss: Experiment 1. Psychophysiology, 11(2), and (NMNRU Report No. 73-21). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit.

Twelve young (17-21 yrs) male Navy recruits volunteered for a sleep loss study. After four baseline days, the Ss were completely deprived of sleep for two days and nights. Next followed an experimental phase of two days and nights after which all Ss received two nights of uninterrupted sleep.

During the experimental phase, the four Ss in the REM-deprived group were aroused whenever they showed signs of REM sleep. The four Ss of the stage 4-deprived group were aroused whenever they showed signs of entering stage 4 sleep, and the four Ss of the control group had uninterrupted sleep.

All tests (speed and accuracy of addition, speed and accuracy of self-paced vigilance, errors of omission in experimenter paced vigilance, immediate recall of word lists, and mood) showed significant impairment after the first night of complete sleep loss. But during the experimental (sleep-stage-deprivation) and recovery phases, all three groups showed equal rates of recovery. Depriving the S of stage REM or stage 4 during recovery sleep does not affect the recuperation

rate. Frequent arousals (50-100 per night) also do not impair recovery. The amount of sleep is probably more important than the kind of sleep.

236. Lubin A., Moses J., & Naitoh P. (1976). Hail sleep: Goodbye REM and slow wave. British Bulletin of Psychology Society, 30, 111-112, (NHRC Report No. 76-37). San Diego, CA: US Naval Health Research Center.

Due credit has not been given to the negative results found by studies that try to relate the kind of sleep deprivation to the kind of performance impairment. There really is little evidence that REM deprivation or Slow Wave sleep deprivation produces much impairment; certainly there is no statistically significant differential impairment. The amount of sleep matters, but the kind of sleep makes little difference.

237. Lyman E. G., & Orlady H. W. (1981). Fatigue and associated performance decrements in air transport operations. (NASA Report No. CR-166167). Mountain View, CA. Battelle Columbus Labs., and Washington, DC: National Aeronautics and Space Administration. (NASA No. N81-22696/1).

A study of safety reports was conducted to examine the hypothesis that fatigue and associated performance decrements occur in air transport operations, and that these are associated with some combination of factors: circadian desynchronosis, duty time; pre-duty activity; sleep; work scheduling; workload; and environmental deprivation. The findings are based on a selected sample of reported incidents in which the reporter associated fatigue with the occurrence. In comparing the fatigue reports with a control set, significant performance decrements were found to exist related to time-of-day, awareness and attention to duty, less significantly, final phases of flights. The majority of the fatigue incidents involved such unsafe events as altitude deviations, takeoffs and landing without clearance, and the like. Considerations of duty and sleep are the major factors in the reported fatigue conditions.

M

238. Mackie R.R., & Miller J.C. (1978). Effects of hours of service regularity of schedules, and cargo loading on truck and bus driver fatigue. (DOT Report No. HS-803 799). Goleta, CA: Human Factors Research, Inc. U.S. Department of Commerce. (NTIS No. PB 290-957).

A literature review, a nationwide survey of commercial truck and bus driver work patterns, an analysis of accident data, and three extensive field experiments were conducted to establish evidence concerning driver fatigue as a function of regularity or irregularity of work schedules, duration of on-duty cycles, participation in supplemental cargo loading work, and type of operation (relay versus sleeper). Data are presented concerning the relative amounts of fatigue experienced by truck and bus drivers under these various conditions, as reflected in their subjective ratings, in various measures of physiological status and in the quality of their driving performance. The results are related to accident data in which fatigued, drowsy or inattentive drivers were reportedly involved. Conclusions are drawn regarding current DOT regulations pertaining to hours of service.

239. Manning F. J. (1985). Human factors in sustaining high rates of artillery fire. (WRAIR-NP-84-7). Washington, DC: Walter Reed Army Institute of Research.

The activities of a US Army field artillery battalion stationed in West Germany were observed both in garrison and in field exercises in an attempt to delineate the implications of continuous operations for commanders at all levels. A number of potentially controllable factors were identified as areas in which actions could extend reliable performance, the most important of which are sleep for leaders, cross-training, care of military dependents, and unit cohesion. The report concludes with 18 specific suggestions for extending performance. Most are applicable to wide branches of the military beyond the artillery community studied.

240. Marchbanks V. H. (1960). Flying stress and urinary 17-hydroxycorticosteroid levels during twenty-hour missions. Aerospace Medicine, 31, 639-643.

Stress evaluations were conducted on fourteen B-52 crew members and the author. Three of the subjects were involved in an original study (1957) of a single 22.5-hour mission. The mean increase in urinary steroids for all personnel was 38 per cent during the first study and 48 per cent during the one reported here.

The time of the mission in relation to the normal rest period influenced the 17-OHCS output. The highest increase occurred during missions flown further from the normal sleep cycle. The findings indicate that urinary excretion of 17-OHCS served as a favorable index for evaluation of stress in flying personnel. The experimental results reported herein are in agreement with similar findings in studies on oarsmen before and immediately after performance.

241. Marchbanks V. H., Hale H. B., & Ellis, J. P., (1963). Stress responses of pilots flying 6-hour overwater missions in F-100 and F-104 aircraft. Aerospace Medicine, 34, 15-18.

Postflight urine and blood samples for pilots flying 6-hour overwater missions in F-100 and F-104 aircraft were collected in an attempt to appraise flying stresses. Comparison was made with a third group of pilots on an off-duty day. Urinary determinations included epinephrine, norepinephrine, corticosteroids (17-OHCS), sodium, potassium, inorganic phosphate, urea, uric and creatinine. Blood determinations included free and conjugated hydrocortisone and corticosterone-like fractions.

Flying raised corticosteroid levels in plasma but not in urine. Levels for the F-100 group were higher than for the F-104. Urinary epinephrine and norepinephrine values for the flying groups were significantly above those for the control values for the F-104 exceeding those for the F-100 group. Differences in flying groups appear to relate to aircraft characteristics, weather conditions, and flying experience. Both flying groups showed high urinary excretion of urea and uric acid, but only in the F-104 group was sodium and potassium excretion elevated. Flying induced no variation in urinary phosphate. Singly and collectively, these determinations are basic to future studies on flight stress.

242. Martin B. J. (1982). Sleep deprivation and exercise tolerance. (IU Report No. 1). Bloomington, IN: Indiana University School of Medicine. (DTIC No. AD A113-043).

The purpose of this study was to identify the effects of sleep deprivation on the ability of humans to tolerate standard forms of endurance exercise. Standard techniques in human exercise psysiology were used. Results indicate acute sleep loss of 30 to 36 hours a) does not alter the maximal oxygen uptake, while it does reduce maximal heart rate; b) leaves metabolic rate during exercise at a constant external work load unchanged, while heart rate is reduced and ratings of perceived exertion are elevated; c) reduces tolerance of prolonged heavy exercise at three-fourths of the maximal oxygen uptake by about 10%, with wide variation noted among individuals, and d) fails to significantly change work loads selected for equal effort during short-term heavy exercise. The authors conclude that acute sleep loss of 30 to 36 hours has relatively minor deleterious effects on endurance exercise performance.

243. McFarland R. A. (1974). Influence of changing time zones on air crews and passengers. Aerospace Medicine, 45, 648-658.

The introduction of jet aircraft into general use has resulted in a technological revolution for both air crews and passengers. Although safe and comfortable, they have introduced a physiological stress for passengers flying east or west, known as the problem of "circadian rhythm," which is essentially induced by the rapid time changes over four or more time zones. Certain intrinsic physiological mechanisms, cyclic in nature, and regulated by stimuli from the day-night cycle of the environment, appear to be disturbed.

In the first part of the paper a brief analysis is presented of the basic physiological rhythms of the body in both man and animals. The findings are then related to air crews and passengers. The specialized studies simulating air transport schedules are then discussed from the point of view of suggested solutions. An example is "Project Pegasus," a study of the effects of air travel across nine time zones. Emphasis is then placed on various factors which may influence or accentuate the effects of rapid flights across time zones. The application of in-flight studies is reviewed and recommendations are made for air crews and passengers.

244. McFarland R. A. (1975). Air travel across time zones. American Scientist, 63, 23-30.

This article discusses physiological problems that occur as a result of rapid travel, east or westbound, across time zones. The paper attempts to highlight some of the more than

200 recent studies that throw light on some of these problems. Desynchronization of circadian rhythms appears to be the cause of many of the physiological and psychological problems known as "fatigue." Other factors influencing these physiological and psychological functions, such as cabin pressure and humidity, are also discussed. Numerous experimental studies are cited and referenced in the text. Some practical suggestions are also given to the air traveler on ways to lessen the severity and readjustment time of circadian desynchronization.

245. McGrath S. D., Wittkower E. D., & Cleghorn R. A. (1954). Some observations on aircrew fatigue in the RCAF-Tokyo Airlift. Aviation Medicine, 25, 23-37.

The men studied were members of a transport squadron which, at the time of the investigation, were engaged in the Tokyo airlift. They flew approximately 100 hours per month. The natural history of the fatigue process forming a composite picture of an average trip is described in the paper. The factors which the men considered relevant to "transient fatigue" may be divided into three main groups:

(A) Factors common to transport flying in general: 1) length of flight; 2) delayed flights and false starts; 3) details prior to take-off; 4) reliability of radio communication and navigational aids; 5) bad weather and anticipation of bad weather; 6) monotony and boredom on familiar routes; 7) the number of intermediate stops; and 8) drinking the night before;

(B) Factors relating specifically to the operating condition of the squadron: 1) problems particular to their DC-6 aircraft; 2) problems particular to this route: conditions after the flight; recreation at stopover points; irregular hours; and

(C) Personal factors: 1) inexperience; 2) tension among the crew; 3) responsibility; 4) relationships to the higher authorities; 5) domestic worries; 6) personality.

246. McIntosh B. E., Milton J. L., & Cole, E. L. (1952). Pilot performance during extended periods of instrument flight. (USAF Report No. WADC TR-6725). Wright-Patterson Air Force Base, OH: Wright Air Development Center.

The purpose of this investigation was to collect exploration data on pilot performance during extended instrument flights. Each of three pilots flew a C-47 aircraft for ten, fifteen and seventeen hours, respectively. Equipment installed in the aircraft permitted recording of (1) amount of time flight indicators were kept within tolerance limits, and (2) continuous variation of flight indicators and control positions. Pilots' introspections and observations by a safety pilot were also obtained after each flight. To supplement the above measures, addition, and reading comprehension tests were

given before during and after the ten hour flight, pilot reaction time to a signal light was taken during the fifteen hour flight and an alertness indicator was operated during the seventeen hour flight. The pilots kept the flight indicators within the specified tolerance limits for both precision maneuvers and straight and level flight as well after 10, 15 and 17 hours of instrument flight as they did during the first hours of these flights.

The results of the graphic records also gave indications that performance, was not a function of time, since no decrement appeared between the first and last portions of the flight. The introspections of the pilots indicate that they became preoccupied with their physical discomfort but they believed they could cope with a critical situation had it appeared. The constant level of their performance indicates they were coping satisfactorily with the flight requirements.

247. McKenzie R. E., & Elliott L. L. (1965). Effects of secobarbital and de-amphetamine on performance during a simulated air mission. Aerospace Medicine, 36, 774-779.

The operational deployment of high performance fighter aircraft on extended missions poses significant problems related to the effects of drugs upon pilot proficiency. This study was designed to simulate a pre-mission crew-conditioning program and 12-hour flight. The research goal was to determine the performance effects of secobarbital taken the night before and of d-amphetamine taken during the mission.

The results of 48 subjects indicated that performance decrement, unpredictable by selected psychologic test scores and not related to gross physiologic measures, occurred as a residual effect of proficiency. Individuals receiving a hypnotic dose (200 mg) of barbital at bedtime demonstrated a performance decrement 10 hours later at the start of their simulated "flight" and continued to demonstrate degraded performance at the completion of their mission 12 hours later. Those subjects who received 5 mg of de-amphetamine "in flight" showed the often documented enhancement of performance, but those who received secobarbital at bedtime and d-amphetamine "in flight" showed an altered performance response curve in terms of increased latency and lower peak performance.

248. Melton, C.E., McKenzie, J.M., Wicks, S.M., Saldivar, J.T. (1981). Fatigue in flight inspection field office (FIFO) flight crews. (FAA Report No. AM-81-13). Oklahoma City: OK: Federal Aviation Administration, Civil Aeromedical Institute. (DTIC No. AD A106-791/7).

Studies related to FIFO aircrew stress and fatigue were carried out at 7 FIFOs in the Continental U.S. Forty-one men served as subjects and all crew positions were represented. Each crewmember was studied during flight activities and during office-based activities. Generally, crews were in travel status during flight inspection activities and away from the office for 5 days. Crewmembers completed fatigue checklists before and after each duty on every workday. Urine specimens were collected that represented the night sleep period and the work period; they were analyzed for 17-ketogenic steriods, epinephrine and norepinephrine; and values were expressed as weight per hundred milligrams of urinary creatine. Ambulatory electrocardiograms were recorded for determination of heart rate (HR) during work.

The data indicate that office work is distinctly less fatiguing than flight work. This finding is supported by the HR data that indicate a lower workload in the office than in flight. The statement is commonly made by crewmembers that office work is more fatiguing than flight work. It is probable that such statements are based on work preferences rather than work level. Some crewmembers at Oklahoma City, Atlanta, Los Angeles and Battle Creek showed severe fatigue associated with flight work.

249. Melton C. E., & Wicks M. (1969). Binocular fusion time in sleep-deprived subjects. (FAA Report No. AM-69-1). Oklahoma City, OK: Federal Aviation Administration Civil Aeromedical Institute. (DTIC No. AD 688-426).

The attainment of binocular single vision when the distance of gaze is changed is a component of total reaction time and may be critical in flight when the gaze is changed from the instrument panel to the outside or from the outside to the instrument panel. This report deals with the effect of fatigue induced by sleep deprivation on the binocular fusion reflex. Binocular fusion times were measured morning and evening in six subjects during 86 hours of sleep deprivation and in six control subjects. The binocular fusion reflex under the experimental conditions employed appeared to be resistant to fatigue incident to sleep deprivation.

250. Mohler S. R. (1966). Fatigue in aviation activities. Aerospace Medicine, 37, 722-732. (FAA Report No. AM-65-13). Oklahoma City, OK: Federal Aviation Administration Civil Aeromedical Institute. (DTIC No. AD 620-022).

This paper provides a survey of work in the field of aviation fatigue. Early work and studies in progress are included. The nature of fatigue itself is discussed along with possible factors that contribute to both physical and mental fatigue. Topics covered include flight-time limitations, indicators of excessive fatigue, new developments related to intercontinental flights and Forest Service flights.

251. Mohler S. R., Dille J. R., & Gibbons H. L. (1968). Circadian rhythms and the effects of long-distance flights. Airline Pilot, 37, 15-17. (FAA Report No. AM-68-8). Oklahoma City, OK: Federal Aviation Administration Civil Aeromedical Institute.

Air travelers crossing four or more time zones experience significant desynchronization of certain daily biologic rhythms. Until rephasing of the rhythms occurs relative to the solar cycle at the destination some subjective discomfort and disruption of psychophysiologic responses can occur. This paper reviews research on diurnal rhythms, discusses the implications for aircrew and passengers, and makes recommendations for reducing the effects of time zone displacements.

252. Monahan R. H. (1974). Technical report sustained operations model: Helicopter War Game Simulator. (DRSAV Report No. TR-76-19). Menlo Park, CA: Stanford Research Institute. (DTIC No. AD A024-444).

The Sustained Operations Model (SOM) is an event sequenced Monte Carlo simulation computer program that uses externally generated cost and single mission effectiveness results to examine the effectiveness of a group of attack helicopter (AH) aircraft operating in a combat environment over a sustained period of operations. The single mission effectiveness inputs used by SOM are generated by an external program such as GLOBAL or EVADE, complex combat simulation programs that evaluate the outcome of an attack by an AH fire team against enemy ground units that include air defense capability. The cost factor is represented in the actual use of SOM, where comparisons of alternative AH systems are based on using equal cost force sizes. Additional cost factors can also be applied to end game results such as aircraft losses, ordnance and fuel expenditures, and maintenance demands, to derive comparative operational costs during the period of operations.

253. Monk T. H., Fookson J. E., Kream J., Moline M. L., Pollak C. P., & Weitzman M. B. (1985). Circadian factors during sustained performance: Background and methodology. Behavior Research Methods, Instruments & Computers, 17,(1), 19-26.

It is well established that there is a complex timekeeping mechanism in the human system. This mechanism is associated with a variety of physiological and psychological rhythms having a period of about a day, and thus referred to as circadian rhythms. The circadian system has recently been modeled in terms of two underlying oscillators: an individuals' body temperature and the sleep/wake cycle. The body temperature is much more resistant to changes in routine than the sleep wake cycle. These oscillators are considered to be endogenous, i.e. internal to the organism, and not reliant for their existence upon changes in the person's environment or general behavior. They thus continue to run, even when the sleep/wake cycle is suspended, as in sustained operations. Thus, by their very nature, sustained operations require the individual to override the inputs that are coming from his or her circadian system (especially the indication that sleep is required).

The aim of this paper is to provide a background to the area of circadian rhythms research, including a large section on the methodology, so that the impact of the circadian system on sustained operations can be better understood.

254. Monk T., Knauth P., Folkard S., & Rutenfranz J. (1978). Memory based performance measures in studies of shiftwork. Ergonomics, 21(10), 819-826.

The phase of the circadian rhythm in performance efficiency on a given task is known to be influenced by the memory load involved. Two experiments were performed to determine whether load also influences the rate at which rhythms adapt to the pase-shifts involved in a) transmeridian flight and b) a long period of nightwork.

In the first study, high and low memory load versions of a performance test were given to a 25y old female subject experiencing a 5h eastward change in time-zone. Differences were found both in the intial phase of the two versions of the test and in the rate at which this phase adapted to the new time. In the second study, two young male subjects, working 21 consecutive night shifts, were given high and low memory load versions of the performance test, and a calculations test, every 4 h around the clock. The results were similar to those in the first study: a cosinor analysis revealed that despite periods of arhythmicity there were large differences between the rate of adaption of the phases of the performance rhythms

of high and low memory versions of the test, and also between the rhythms of temperature and performance. It is concluded that it is wrong to speak of a single "performance rhythm", and that performance tests in shiftwork and jet-lag studies should thus simulate some aspect of the "real" task under consideration.

255. Morgan B. B. (1974). Effects of continuous work and sleep loss in the reduction and recovery of work efficiency. American Industrial Hygiene Association Journal, 35, 13-20.

The synthetic-work technique has been employed in a series of investigations designed to determine (a) the extent to which performance efficiency is degraded during extended periods of continuous work, and (b) the amount of sleep necessary for the recovery of performance from the effects of continuous work and sleep loss. The results of these studies indicate that 36, 44, and 48 hours of continuous work and sleep loss result in decrements in over-all work efficiency of approximately 15%, 20%, and 35%, respectively.

Following 36 hours of continuous work, it was found that 12 hours of sleep is sufficient for complete (100%) recovery of performance, but complete recovery is not provided by 2 (58% recovery), 3 (53% recovery), or 4 (73% recovery) hours of sleep. The time course of recovery is different following different durations of continuous work and subsequent sleep.

256. Morgan B. B., & Alluisi E. A. (1972). Synthetic work: Methodology for assessment of human performance. Perceptual and Motor Skills, 35, 835-845.

The synthetic-work approach has provided one of the most important methodologies for the assessement of human performance. The basis of this approach is a laboratory work situation in which Ss work for 8 hr. per day over periods of 12 to 15 days at a job consisting of 6 tasks which have been embedded in a multiple-task performance battery (MTPB). Descriptions of each of the 6 tasks, the integration of the tasks into a job or synthetic-work situation, and the use of the methodology in assessing human performance are presented along with a summary of research conducted with this methodology.

257. Morgan B. B., Brown B. R., & Alluisi E. A. (1974). Effects on sustained performance 48 hours of continuous work and sleep loss. Human Factors, 16, 406-414.

The work efficiency of 10 subjects during a 48-hour period of continuous work and sleep loss was assessed using the synthetic work technique. Performance during the period of

stress was found to be significantly influenced by the circadian rhythm. Decrements first occurred after approximately 18 hours of continuous work, and performance decreased to an average of 82% of baseline during the early morning hours of the first night. Performance improved to about 90% of baseline during the day time of the second day but decreased to approximately 67% during that night. All measures of performance recovered to baseline levels following a 24-hour period of rest and recovery.

258. Morgan B. B., Brown B. R., Coates G. D., & Alluisi E. A. (1975). Sustained performance during 36 hours of continuous work and sleep. (PRL Report No. ITR-75-31). Louisville, KY: University of Louisville, Performance Research Laboratory.

The synthetic-work approach was employed to investigate (a) the decrements in performance produced by 36 hr of continuous work and sleep loss, and (b) the recovery of performance from these decrements as a result of 12 hrs of rest and recovery. Ten Navy and Air Force cadets worked the tasks of a multiple-task performance battery (MTPB) during a 4-week training period. Subsequently, they worked 8 hr on each of 2 days, then worked continuously for 36 hr, observed a 12-hr period of rest and recovery, and finally, worked 8 hr on each of 2 additional days.

Performance during the 36 hr of continuous work was greatly influenced by the circadian rhythm. The first performance decrements occurred after approximately 18 hr of work, during the early morning hours of the first night; average performance decreased to approximately 92% of baseline performance. During the first half of the second day of continuous work (by the end of the 36 hr), performance improved to about 97% of baseline. All measures of performance indicated that the recovery of performance was complete (to baseline levels) following the 12-hr period of rest and recovery.

These results essentially replicate those of an earlier study that required 48 hr of continuous work and sleep loss followed by 24 hr of rest and recovery. Results from both these studies are compared to those of four previous investigations of the effects of sleep loss; four factors that contribute to the decrements obtained during periods of continuous work and sleep loss are identified and discussed.

259. Morgan B. B., & Coates G. D. (1974). Sustained performance and recovery during continuous operations. (PAL Report No. ITR-74-2). Norfolk, VA: Old Dominion University, Performance Assessment Laboratory. (DTIC No. AD A012-908).

Two papers based on studies of continuous work and recovery are presented. Results summarized herein suggest that performance decrements during 36 hr of continuous work and sleep loss will vary between 11 and 35% depending upon the time of day at which the continuous-work session begins. It is also suggested that appropriately scheduled military personnel will be be able to maintain acceptable levels of performance during 36 hr of continuous field operations and that these personnel will require 6 to 8 hrs of sleep before they are ready to return to duty.

260. Morgan B. B., Coates G. D., Brown B. R., & Alluisi E. A. (1972). Effects of symptomatic treatment on sustained performance during illness with phlebotomus fever. (PAL Report No. ITR 72-23). Louisville, KY: Performance Research Laboratory, University of Louisville. (DTIC No. AD 759-496).

The results of the seventh (BEID-7) and eighth (BEID-8) in a series of long-term multiple-task performance studies of the behavioral effects of infectious diseases are reported. The 15-day BEID-7 study was conducted at the U. S. Army Medical Research Institute of Infectious Diseases, Fort Detrick, Maryland, with 10 volunteer subjects, nine of whom were infected with Phlebotomus (Pappataci or Sandfly) fever virus. Symptomatic treatment (aspirin and Darvon) was initiated for each subject at the onset of symptomatic illness and continued for a period of 48 hr. BEID-8 was a 12-day control study, conducted at the University of Louisville, in which 10 uninfected subjects received symptomatic treatment identical to that administered to the infected BEID-7 subjects. Subjects in both studies followed a work-rest schedule of 4 hr. on-duty, 4-hr. off, 4 on, and 12 off.

Analyses of the sustained performance data indicate that essentially no decrements occurred during the period of illness and chemotherapy in BEID-7. The aspirin and Darvon treatment served to eliminate the 18 to 25% average decrement in performance typically found in previous studies of the behavioral effects of Phlebotomus fever. The symptomatic chemotherapy had no effect on the performance of the uninfected subjects in the BEID-8 control study.

261. Morgan B. B., Coates G. D., Brown B. R., & Alluisi E. A. (1973). Effects of continuous work and sleep loss on the recovery of sustained performance. (HEL Report No. TM 14-73). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

A synthetic-work methodology was employed in a series of eight studies conducted to provide definitive information concerning the time course of performance recovery from the detrimental effects of 36 and 44 hours of continuous work and sleep loss. Two crews of five subjects served in each of four continuous-work/recovery conditions in partially counter-balanced order, namely: (a) 44 hours of continuous work followed by 4 hours of rest and recovery (sleep), (b) 36 hours continuous work/ 4 hours rest and recovery, (c) 36/3, and (d) 36/2.

The results indicated that both the degree and pattern of performance recovery were related to the length of the continuous work period as well as to the amount of subsequent sleep provided. The 36-hour continuous work period was associated with decrements of 14-18% in performance efficiency while the 44-hour period resulted in a decrement of about 22%. Following 36 hours of continuous work, 2, 3, and 4 hours of sleep yielded an immediate recovery in performance of about 76%, 56%, and 75%, respectively, whereas 4 hours of sleep following 44 hours of continuous work produced only 39% immediate recovery.

It is suggested that 6-8 hours is the minimum amount of sleep required for the recovery of performance from the effects of 36 hours of continuous work and sleep loss.

262. Morgan B. B. & Pitts E. (1985). Methodological Issues in the Assessment of Sustained Performance. Behavior Research Methods, Instruments & Computers, 17,(1), 96-101.

In both military and industrial work settings it has become desirable, and in many instances necessary, to require sustained performance beyond the apparently optimal 8-hour workday. Research in this area may be viewed historically as having been focused in three major areas: (1) determining appropriate methodologies for measuring sustained performance, (2) investigating factors which influence sustained performance, and (3) searching for ways to enhance performance during sustained operations. Observations concerning methodological issues in this research are drawn from a discussion of presentations made at the Sustained Operations Workshop held at the Canadian Defence Civil Institute of Environmental Medicine (DCIEM), Toronto (August 23, 1984) and the American Psychological Association Symposium on Sustained

Work, also held in Toronto (August 25, 1984). Based on these general observations, recommendations are made concerning the directions and content of future research.

263. Morgan B. B., Winne P. S., & Dugan J. (1980). The range and consistency of individual differences in continous work. Human Factors, 22(3), 331-340.

Two five-man teams were trained to asymptotic levels of synthetic-work performance on a multiple task performance battery (MTPB) which required subjects to time share five individual performance tasks and one group performance task. Each team was then exposed four times to continuous work and sleep loss stresses in a repeated measures design.

Performance levels were measured in terms of 13 individual task measures and a general mean-percentage-of-baseline measure. Individual performance decrements were found to range from 0 to 40% below pre stress levels. The findings also indicated that subjects responded consistently across the four exposures to continuous work and sleep loss. Furthermore, the subjects experienced a general performance decrement across all tasks rather than a task-specific one. These findings are discussed in terms of their important implications for the design of man-machine systems and the selection of operators who are most resistant to sleep loss stress.

264. Morgan Management Systems, Inc. (1984). The management of sleep and stress in continuous operations. (Morgan Management Systems Contract Final Report). Columbia, MD: Morgan Management Systems, Inc.

This study was initiated as a result of the U.S. Army's need to study the effects of stress and sleep loss anticipated in the future concept of warfare-- the Air-Land Battle. Future wars will be characterized by highly lethal weapons, isolation of units, fluid and mobile tactics, the threat of Nuclear, biological and chemical weapons, and the need to function for extended periods of time--up to 332 hours--without adequate rest or replacements. Knowing these things, commanders must prepare their troops for fighting and winning under such conditions.

These factors also shaped the components of the study, namely: a) the need for a computer-based literature search to establish a preliminary data base/bibliography on the popular literature and research findings on the subjects of sleep and stress, b) development of training publications on stress and sleep management to prepare small unit leaders and the individual soldier for fighting effectively in continuous operations by employing counter degradation measures, and c)

analyzing the PERFECT and AMORE combat simulation models and preparing a program interface demonstrating the interaction of the two programs for potential use as input for the Air-Land Battle Study.

265. Mortagy A. K., & Ramsey J. D. (1972). Monitoring performance as a function of work/rest schedule and thermal stress. (Texas Tech. THEMIS Report No. 603). Lubbock, TX: Texas Tech University, Center of Biotechnology & Human Performance. (DTIC No. AD 752-071).

This study evaluates the effects of work/rest schedules as a means of retarding job fatigue and maintaining vigilance performance in hot climates. Six different work/rest schedules were investigated at three levels of heat stress (74, 82, and 90 degrees FFT). Experimental sessions were three hours long for each of the 108 subjects used. Results show that the factors of temperature, work period and work/rest ratio of the levels utilized in the study did not, by themselves, affect vigilance performance to a high degree. However, when high temperatures, long work periods, and short rest periods occurred in combination, a disproportionate decrement in monitoring performance was observed.

266. Moses J. M., Hord D. J., Lubin A., Johnson L. C., & Naitoh P. (1975). Dynamics of nap sleep during a 40 hour period. Electroencephalography and Clinical Neurophysiology, 39, 627-633.

Following 1 baseline night, the sleep of 8 adult males in equally spaced 1 h naps during a 40 h period was examined. Ten additional subjects were sleep-deprived for 40 h with 1 h periods of exercise given in place of naps. One recovery night followed the 40 h period for both groups. Total sleep time and the amount of stage REM during the naps were negatively related to the circadian-temperature cycle. Stage REM frequently appeared within 10 min of stage 1 onset and the normal sequence of stages REM and 4 were altered, demonstrating that the organization of sleep within a nap is quite different from that in monophasic nocturnal sleep. Auto-correlation and cross-correlation analyses showed that the relation of sleep stages from hour to hour in normal continuous baseline sleep was altered in nap-to-nap comparison. The timing of REM onset may be controlled by a sleep-dependent ultradian clock; the clock may stop upon awakening and resume at the next sleep onset. Naps had recuperative value in terms of maintaining the normal amounts of sleep stages on the recovery night; recovery sleep for the exercise group showed typical sleep-loss effects.

267. Moses J., Lubin A., Haitoh P., & Johnson L. C. (1974). Subjective evaluation of the effects of sleep loss: the NPRU mood scale. (NHRU Report No. 74-25). San Diego, CA: US Naval Health Research Center.

A mood scale consisting of 52 adjectives and phrases was given to twelve young naval recruits to determine which items were sensitive to at least one night of sleep loss. The items which were maximally sensitive to sleep loss were then used to measure the effects of one night of total sleep loss in another group of fourteen young naval recruits. The two experiments resulted in a list of 29 adjectives and short phrases, the NPRU Mood Scale. This scale can be easily, briefly, and repeatedly employed to detect cumulative sleep loss and to assist in evaluating task performance decrement.

268. Moses J., Lubin A., Naitoh P., & Johnson L. C. (1977). Exercise and sleep loss: Effects on recovery sleep. Psychphysiology, 14(4) and (NHRC Report No. 76-68). San Diego, CA: US Naval Health Research Center.

The effects of exercise and sleep loss on recovery sleep were studied in young male naval volunteers. For 1 hr out of every 4 hrs during a 40-hr period, 20 subjects rested in bed and 10 subjects bicycled. Eleven measures of recovery night sleep were selected for comparison of the bedrest and exercise groups. Only one reached significance under the conservative Dunn-Bonferroni criterion: the exercise group had a higher percent total sleep time. The results indicate that exercise does increase the effects of sleep loss on recovery sleep, but that there is no simple, direct effect on specific sleep stages.

269. Moses J., Lubin A., Naitoh P., & Johnson L. C. (1978). Circadian variation in performance, subjective sleepiness, sleep, and oral temperature during an altered sleep-wake schedule. Biological Psychology, 6, 301-308, and (NHRC Report No. 78-2). San Diego, CA: US Naval Health Research Center.

The effect of an altered sleep-wake schedule on the interrelation of oral temperature, performance, and sleepiness was studied in 38 male Naval volunteers who maintained a 60 min treatment - 160 min testing schedule for 40 consecutive hrs. During the 60 min treatment portion of each epoch, 8 subjects napped, 10 subjects exercised, and 20 subjects rested in bed. Sleep measures (for the nap subjects), oral temperature, performance on several tests, and Stanford Sleepiness Scale ratings were obtained at 10 equidistant intervals throughout the 40-hr period.

Within-subject correlations showed that minimum oral

temperature was significantly associated with maximum nap sleep time, errors on a vigilance task, and sleepiness ratings. In the nap subjects, errors and sleepiness ratings were highest following naps with high total sleep time, suggesting that sleep was detrimental to performance and alertness. The distribution and interrelation of temperature, errors, and sleepiness, however, was similar in the three groups; this indicated that the synchronous circadian variation in these measures was responsible for the apparent detrimental effect of sleep in the nap subjects. When the diurnal effect was removed by holding time of day constant, the correlations among the variables fell to near zero, indicating no causal relationship among the variables independent of the circadian rhythm.

270. Moses J., Naitoh P., & Johnson L. C. (1978). The REM cycle in altered sleep/wake schedules. Psychophysiology, 15(6), and (NHRC Report No. 77-37). San Diego, CA: US Naval Health Research Center.

The length and rhythmicity of the REM cycle was studied using data from three laboratories. In the three studies, 25 subjects obtained their sleep in naps under three different sleep/wake schedules: 60/160 min (N=8), 30/60 min (N=10), and 60/120 min (N=7), over periods of 40 hrs to 10 days. Previous results from these subjects indicated that the REM cycle is sleep-dependent, rather than an expression of an ongoing Basic Rest-Activity Cycle (BRAC). As a further test of the sleep-dependent hypothesis, autocorrelation and correlation analysis were applied to the compressed sleep (i.e., all wake time between and within sleep periods subtracted) of the baseline, nap, and recovery conditions.

Compared to baseline, there were no significant differences in nap REM cycle length in the 60/160 and 60/120 groups; the 30/60 group had significantly shorter cycles. It appeared that this REM cycle shortening was due to the significantly shorter REM episodes in this group. The nap correlation values were significantly lower than baseline in the 30/60 and 60/120 groups, indicating increased variability in the timing of REM episodes during naps. All the nap correlation values, however, were significantly larger than those obtained from a random distribution of sleep stages.

Two additional groups of subjects whose sleep was fragmented by either REM or SWS deprivation were compared to the nap groups. REM deprivation was the most disruptive of REM cycle rhythmicity; the correlation values for REM deprivation were significantly less than those for napping or SWS deprivation. These data offer further support that the REM cycle is a sleep-dependent rhythm and is not an expression of an ongoing BRAC.

271. Mullaney D.J., Fleck P.A., Okudaira N. & Kripke D.F. (1985). An automated system for administering continuous workload and for measuring sustained continuous performance. Behavior Research Methods, Instruments & Computers 17(1), 16-18.

Sustained continuous performance for up to 42 h was studied with 60 male volunteers in two separate protocols. The recuperative value of six 1-h nap breaks and a single 6-h break were contrasted in 20 subjects, 10 in each nap group. Forty other subjects attempted to work continuously with no breaks for 42 h. Twenty of these subjects worked simultaneously on separate parallel computer-based tasks, but worked in the same room in pairs. All subjects in the two nap groups (N=10 and N=10), as well as 20 who had no scheduled breaks, worked alone, almost isolated, with minimal interaction with the experimenters. During each 10 min, subjects performed a tracking task, a pattern-memory task, and an addition task and provided subjective ratings on sleepiness and attention/fantasy. Results showed that computerized tasks demanding sustained continuous performance without naps cause more rapid performance deterioration than previously tested intermittent-work paradigms.

272. Mullaney D. J., Kripke D. F., & Fleck P. A. (1981). Sleep loss effects on continuous sustained performance. (Department of Psychiatry Report No. 1). La Jolla, CA: Department of Psychiatry, University of California.

The ability to sustain continuous performance for up to 42 hours was studied. During each 10 minutes, subjects performed a tracking task, a pattern memory task, an addition task, a simultaneous auditory vigilance task, and provided subjective ratings on sleepiness and attention-fantasy scales. Of 10 subjects required to work continuously with no breaks, 3 could not complete the 42 hours, and 8 out of 10 suffered symptoms such as hallucinations, visual illusions, and disorientation. Subjects provided either six 1-hour naps or one 6-hour sleep period were able to complete the 42-hour study and suffered fewer psychiatric symptoms. The group working continuously suffered marked impairments of performance, especially in the addition task, while those receiving 1-hour or 6-hour rest periods sustained their level of performance much more effectively. These results show that when absolutely continuous sustained work is required, performance deteriorates seriously even within the first 24 hours.

273. Mullaney D. J., Kripke D. F., Fleck P. A., & Okudaira N. (1983). Effects of sustained continuous performance on subjects working alone and in pairs. Perceptual and Motor Skills, 57, 819-832.

Sustained continuous performance for up to 42 hr. was studied with 30 male volunteers. During each 10 min., subjects performed a tracking task, a pattern-memory task, an addition task, and provided subjective ratings on sleepiness and attention-fantasy scales plus a brief written description summarizing their thoughts. Of the 10 subjects required to work alone, 4 did not complete the 42 hr. and 9 experienced "psychological events" such as hallucinations, visual illusions, and disorientation. Of the 20 subjects who began the 42-hr. task in pairs, 5 did not complete the 42 hr. and 13 experienced similar psychological events. The percentage who did not complete the 42 hr. of the study and the incidence of psychological events were not significantly different for subjects working alone and in pairs. Performance results were very similar.

No significant relationship of psychological events to any of the performance measures was demonstrated. These results indicate that continuous sustained performance produces rapid deterioration of performance and psychological disturbances, regardless of the presence or absence of social contact.

274. Mullaney D. J., Kripke D. F., Fleck P. A., & Johnson L. C. (1983). Sleep loss and nap effects on sustained continuous performance. Psychophysiology, 20(6), 643-651.

Thirty young male volunteers participated in a study of sustained continuous performance using a variety of computer-based tasks. After 6 hrs of recorded sleep, 10 subjects were assigned to perform continuously for 42 hrs without break. Four of these subjects were unable to complete the 42-hr assignment, and 8 of the 10 suffered psychological events such as hallucinations and disorientaation. Ten subjects permitted six 1-hr naps over the 42 hrs performed more successfully than those allowed no sleep. Ten subjects permitted one 6-hr rest period performed best of all. Fatigue effects appeared after 6 hrs. Time-of-day (circadian) effects were at times stronger than fatigue.

275. Mullaney D. J., Kripke D. F., Fleck P. A., & Okudaira N. (1982). Sleep loss effects on continuous sustained performance. (Department of Psychiatry Report No. 3). La Jolla, CA: Universtiy of California.

The ability to sustain continuous performance for up to 42 hours was studied with 30 subjects. During each 10 minutes,

subjects performed a tracking task, a pattern memory task, and provided subjective ratings on sleepiness and attention-fantasy scales plus a brief written description summarizing their thoughts. Of the 10 subjects required to work alone, 4 did not complete the 42 hours and 9 experienced "psychological events" such as hallucinations, visual illusions, and disorientation. Of the 20 subjects who began the 42-hour task in pairs, 5 did not complete the 42 hours and 13 experienced similar psychological events. The percentage who did not complete the 42 hours of study and the incidence of psychological events were not significantly different for subjects working alone and in pairs.

Performance results were vary similar. No significant relationship of psychological events to any of the performance measures was demonstrated. These results indicate that continuous sustained performance in itself causes rapid deterioration of performance and psychological disturbances, regardless of the presence or absence of social contact.

276. Mullaney D., Kripke D. F., & Messin S. (1980). Wrist-actigraphic estimation of sleep time. Sleep, 3(1), 83-92.

Using a piezoelectric transducer, wrist activity was recorded simultaneously with electroencephalogram (EEG), electro-oculogram (EOG) recordings and submental electromyogram (EMG) to obtain 102 recordings-- 39 from hospital patients and 63 from nonpatients. On a minute-to-minute basis, wrist activity alone was used to estimate Sleep Time. Blind independent scoring of the EEG-EOG-EMG records was also done to distinguish Sleep and Wake phases. Results from the two Sleep/Wake estimations agreed for 94.5% of the minutes (96.3% among nonpatients). Correlations between the two methods were determined for Total Sleep Period (r=0.90), Total Sleep Time (r= 0.89), Wake After Sleep Onset (r= 0.70), and the number of Midsleep Awakenings (r=0.25). Correlation coeficients were higher when the 39 patients were excluded from the computations. On the average, the actigraphic method over-estimated Sleep Time by 15 min. Continuous wrist activity recordings provide simple and inexpensive, but rather accurate, estimates of sleep duration.

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277. Naitoh P. (1969). Sleep loss and its effects on performance. (NHRC Report No. 68-3). San Diego, CA: US Naval Health Research Center.

The effects of sleep loss on human task performance are discussed under total, partial, and selective deprivations of sleep. Some of the frequently used psychological tasks in studies of total sleep loss are described in sufficient detail so that experimenters can choose, on the basis of materials presented in this monograph, adequate tasks to fit their experimental objectives. Factors which play critical roles in determining the degree of task sensitivity to total sleep loss are listed. Effects of shortened hours of sleep on human task performance were discussed. Effects of selected sleep deprivation on performance are also briefly commented upon.

This monograph covered almost all studies conducted on sleep loss under laboratory conditions, including a series of on-going experiments on total and selective sleep deprivations at the Navy Medical Neuropsychiatric Research Unit. A bibliography on sleep deprivation with author and subject indices is presented.

278. Naitoh P. (1980). Circadian cycles and restorative power of naps. (NHRC Report No. 80-11). San Diego, CA: US Naval Health Research Center.

An experiment was conducted on two groups of young sailors to study the recuperative power of a nap on task performance and self-ratings of mood, fatigue, sleepiness, and arousal. One group took a 2-hour nap from 0400-0600 (the early morning nap) after 45 hours of continuous work. Six hours later, this group took their second 2-hour nap from 1200-1400 (the midday nap). For the second group, their only nap was from 1200-1600 after 53 hours of continuous work. Circadian rhythm analyses confirmed that the early morning nap was placed near the troughs of many circadian rhythms and the midday nap on the rising limb of the circadian rhythms. A multivariate two-sample profile analysis revealed that the early morning nap resulted in severe and prolonged sleep inertia, and it did not have any recuperative power. In contrast, the midday nap produced a relatively short sleep inertia and had clear

recuperative power. Thus, the recuperative power of a nap depended not only on its duration but, more importantly, on the hours of prior wakefulness and time-of-day when it was taken.

279. Naitoh P. (1981). Circadian cycles and restorative power of naps. In L.C. Johnson, D.I. Tepas, W.P. Colquhoun & M.J. Colligan (Eds.) The twenty-four hour workday. Proceedings of a symposium on variations in work-sleep schedules. (DHHS-NIOSH Report No. 81-127, pp. 693-720). Cincinnati, OH: US Department of Health and Human Services, National Institute for Occupational Safety and Health.

Sleep-deprived men and women show deterioration in mood and behavioral efficiency. A nap is viewed by many as having recuperative power, reducing fatigue and sleepiness. However, if a subject does not habitually nap, the initial effects of a nap would be detrimental to mood and task performance.

Although naps may help in maintaining performance over long periods, the immediate performance upon awakening from a nap may show no improvement and often may be lower than pre-nap levels.

The primary purpose of this study was to determine the recuperative power of a 2-hour nap after either 45 hours or 53 hours of a vigil. The recuperative power was simply defined as those beneficial effects that restore human behavioral efficiency and subjective feelings of vigor and arousal. This study also attempted to answer whether the recuperative power of a nap would depend on the time of day it was taken. The study design and results are described in this report.

280. Naitoh P. (1982). Chronopsychological approach for optimizing human performance. (NHRC Report No. 80-9). San Diego, CA: US Naval Health Research Center.

A new interdisciplinary science of chronopsychology is discussed with respect to its methods, concepts, theories, and applications, especially to shiftwork and transmeridian dyschronism ("jet lag"). Chronopsychology is introduced to show the impact of circadian rhythmic components, as seen in shiftwork and transmeridian flight environments, on human performance efficiency, feeling-tones, fatigue, and sleepiness. The source materials on circadian components of human effectiveness in shiftwork and in a rapid deployment across many time zones suggest that the timing of the work period should be optimized on the basis of the fundamental circadian rhythms to assure the best time for work and rest. Differences between the adjustment of shiftworkers and jet travelers to new work environments are discussed, with suggestions on how to accelerate this process.

281. Naitoh P., Beare A. N., Biersner R. J., & Englund C. E. (1981). Altered circadian periodicities in oral temperature and mood in men on an 18-hour work-rest cycle during a nuclear submarine patrol. (NHRC Report No. 81-1). San Diego, CA: US Naval Health Research Center.

A group of nuclear submariners was studied to examine whether an 18-h routine imposed by a watch-standing schedule of 6-h on, 12-h off during a prolonged submerged patrol affected the 24-h circadian rhythm in oral temperature, Thayer's activation, Mood "Activity" and Mood "Happiness." The submariners were observed during three sections of the patrol: Phase 1, the beginning 8-day period; Phase 2, the middle of the voyage; and Phase 3, the last 7-8 day period of the 10-week voyage.

The group-synchronized 24-h rhythm in oral temperature disappeared during Phase 3. The group-synchronized 24-h rhythms in Thayer's activation and in Mood "Activity" and "Happiness" disappeared during Phases 2 and 3. A group synchronized 18-h rhythm was not produced in any of the variables in any Phase of this study. except MH during Phase 2. Periodicity analysis of individuals' data showed that a loss of 24-h rhythmicity in oral temperature was due not only to reduced circadian amplitude but also to a dispersion of times-of-peak (TOPs). Loss of 24-h rhythm in "Activation" "Happiness," and "Activity" was predominantly due to a wider dispersion of TOPs. The 18-h routine did appear to exert a small modulating effect on rhythmic activity in the variables examined in this study.

Since the sleep-wakefulness cycle was well entrained by the 18-h routine, the submariners experienced a spontaneous internal desynchronization between the activity cycle on the one hand and the cycles of oral temperature and psychological states on the other. The performance and health consequences of this chronic desynchronism have yet to be explored. Further research is suggested to determine the usefulness of an index of synchronization among the physiological and psychological variables, and the relationship of the desynchronizing effects to performance and health.

282. Naitoh P., Englund C. E., Moses J., & Spinweber C. L. (1979). Effects of vigil on human circadian rhythms: Normative data. (NHRC Report No. 79-30). San Diego, CA: US Naval Health Research Center.

A vigil of up to 45 hours does not destroy circadian cycles in physiological and subjective mood scales, but some rhythms in task performance disappeared with vigil. Vigil does, however, alter some basic parameters of circadian

rhythmicity. It tends to reduce strength of rhythmicity and most importantly, to create lengthening of 95% confidence arc for acrophase angles, resulting in appreciably larger 95% confidence ellipse. Thus, major altering effects of vigil of two nights seem to be in a greater scatter of acrophase angles among the individual subjects. Such a greater scatter in time of minimum and maximum due to vigil would result in reduction of amplitude when averages across subjects were plotted along time of day, and also in failure to find a significant cosinor for a group, even though individual subjects might have somewhat reduced but still significant rhythmicity. Relationship between oral temperature and subjective mood and pulse seems to continue undisturbed during the vigil, but correlation between oral temperature and task performance did not survive a process of remaining awake. Findings suggest that more attention must be paid to individual susceptibility to vigil in circadian cycle studies.

283. Naitoh P., Englund C. E., & Ryman D. H. (1982). Restorative power of naps in designing continuous work schedules. Journal Human Ergology. 11, Suppl., 259-278, and (NHRC Report No. 82-25). San Diego: US Naval Health Research Center.

Many occupations involve continuous work (CW) for extended periods of time. Recovery from the fatigue and sleepiness incurred by persons in CW is usually accomplished by short sleep (naps) before embarking on another episode of CW. Previous studies have shown that naps have a restorative effect on task performance, mood and motivation for work. However, recent studies at NHRC suggest that a 2-hour nap from 0400 to 0600 following 45 hours CW failed to restore performance and mood, whereas a 1200 to 1400 nap after 53 hours CW was effective in restoring performance and mood. Thus, time-of-day of naps has determined the "restorative power".

In this paper, data from 38 U.S. Marine Corps volunteers are presented to show that the restorative power of a 0400 to 0700 nap is sufficient to support post-nap performance of a Four Choice task for an additional 20 hours. This early morning 3-hour nap also reduced the rate of degradation of performance of subjects on Four Choice and Simple Reaction Time tasks, in comparison with those who worked without napping. To assure overall high quality performance in recurring episodes of CW, design of work/rest schedule should call for 3 hours or longer of recovery sleep even after CW as short as 20 hours. A model of CW/nap length effects on performance is presented as an aid to conceptualizing the beneficial effects of naps.

284. Naitoh P., Englund C. E., & Ryman D. H. (1983). Extending human effectiveness during sustained operations through sleep management. (NHRC Report No. 83-13). San Diego, CA: US Naval Health Research Center; and in S.E. Forshaw (Ed.), Defence Research Group Proceedings of the 24th DRG Seminar on The human as a limiting element in military systems: Systems, Volume 1. (1983). Toronto, Canada: NATO Defence Research Group.

Sustained Operations (SUSOPs) represent a prolonged period of continuous work (CW) in the performance of essential services. In many military operations, demands for CW cannot be easily met by orderly sharing of work through arranging soldiers on "shift or night work" schedules. Especially during times of emergency, military personnel must often work continuously without sleep for long hours at physically demanding tasks while remaining mentally alert.

This technical paper summarizes four SUSOPS studies, conducted at the Naval Health Research Center, to describe cognitive performance decrements due to continuously working for two episodes of 20 hours each, with a short sleep period of 3 or 4 hours permitted between these two CWs. This paper also reports on an application of "sleep logistics" in evaluation of effectiveness of napping in the early morning period to counteract performance decrement due to a CW. Short napping of 3 or 4 hours in the early morning was found not to be completely effective in restoring Marine Corps volunteers from fatigue and sleepiness of 20 hours CW, thus making them ready to resume the second 2-hour CW with high quality performance. However, some task performances were found to be improved by napping. These findings suggest that napping can be used as an effective intervention technique for maintaining and even enhancing cognitive performance during CW.

285. Naitoh P., Johnson L. C., & Lubin A. (1972). The effect of selective and total sleep loss on the CNV and its psychological and physiological correlates. (NMNRU Report No. 72-9). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit.

The contingent negative variation (CNV) from the vertex was recorded, together with autonomic variables, vertical eye movements, and reaction time (RT), from two groups of 7 Naval trainees each. The subjects received the first stimulus (SI) which was either a "high" or "low" pitched tone, 4 sec before the second "low" pitched tone (S2). With the high pitched SI, the subjects did not terminate the S2. With the low pitched S1, they were to terminate the S2 quickly as posible by closing a hand-held switch. In half of the trials, the experimenter determined the rate of executing the RT task (a work-paced condition); in the remaining half, the subject performed the RT

task at their own preferred pace (self-pacing).

On each subject data were obtained on 4 baseline days, the day after 3 nights of sleep stage deprivation, the day after one night of total sleep deprivation, and finally 2 days following recovery sleep. For the one group, sleep stage REM (rapid eye movement) was withheld from nocturnal sleep. For another, the slow wave sleep (SWS) was denied.

All subjects developed a stable discriminated CNV as well as an anticipatory heart rate deceleration to the S2 in the baseline sessions. Both REM and SWS deprivation reduced the CNV magnitudes under the self-paced condition. One night of total sleep following 3 nights of sleep deprivation attenuated the CNV further. Anticipatory heart rate decrease to the S2 was not affected by REM, SWS or total sleep deprivation.

Results support the hypothesis that the CNV, but not the autonomic correlates, could be used as a reliable and sensitive measure of an altered brain capacity to maintain an attentive state.

286. Naitoh, P., Kales A., Kollar E. J., Smith J. C. & Allen J. O. (1968). Electroencephalographic activity after prolonged sleep loss. (NMNRU Report No. 68-20). San Diego, CA: US Navy Medical Neuropsychiatric Resarch Unit.

The major effect of prolonged sleep loss on the EEG is alpha reduction and this is accompanied by deterioration of subjective ratings of feeling tone, by low 17-OHCS, by degradation of tracking performance, and by reports of hypnagogic illusions. Observed low voltage EEG after sleep loss of 100 hours or more seems equivalent to sleep stage 1, or drowsy EEG pattern. After two nights of recovery sleep (12 and 8 hours), return to pre-deprivation levels of functioning is virtually complete.

287. Naitoh P., Pasmau R. O., & Kollar E. J. (1971). Psychophysiological changes after prolonged deprivation of sleep. Biological Psychiatry, 3, 309-320, and (NMNRC Report No. 71-26). San Diego: US Navy Medical Neuropsychiatric Research Unit.

Four healthy young adult males were studied during 205 hr of sleep deprivation. Resting autonomic measurements included heart rate, blood pressures, oral temperature, and skin resistance. Body weight and electroencephalograms (EEGs) were also evaluated. In addition, the autonomic nervous system (ANS) responsiveness and its recovery were tested by the cold pressor stimulus. Sleep loss of up to 120 hr deactivated the central nervous system (CNS) as judged by EEG alpha time, but

it produced a mixed pattern of deactivation of the ANS. Around the "fifth day" of sleep loss, a yet-undefined adaptive mechanism was actuated, allowing a slow shift of the oral temperature as well as EEG alpha time toward the predeprivation level, coincident with increased secretion of 17-hydroxycorticosteroid. A simple notion of generalized activation and deactivation could not account for a complex bodily mechanism during sleep loss, and the vigil did not produce a Selye-type generalized stress reaction.

288. Naitoh P., & Townsend R. E. (1970). The role of sleep deprivation research in human factors. Human Factors, 12(6), 575-585.

Sleep loss is a ubiquitous phenomenon that occurs on many long-term field missions. The effects of sleep loss are detrimental to efficient functioning of man-machine systems. To illustrate the effect of sleep loss on task performance, data from four independent research institutes are reviewed. Data are presented relating to the prevention of sleep loss, and to the detection and minimization of sleep loss effects when they occur.

289. Naitoh P., Townsend R., & Greenwood M. (1969). Sleep requirements of man-in-the-sea. (NMNRU Report No. 68-22). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit. (DTIC No. AD 695-377).

Despite recent scientific and technological gains in realizing the goal of manned underwater stations, there has been a singular lack of research data on defining the sleep requirements of man-in-the-sea. Behaviorally, sleep loss and sleep disturbances produce lapses in performance and impairment of short-term memory, either of which may endanger the mission or the life of the entire crew of an ocean floor habitat. Interpersonal difficulties may also arise as a result of undesirable personality changes caused by sleep disturbances, thereby weakening the very root of the miniature society of the ocean floor habitat. Research efforts must be spurred on to learn: (1) Whether man as an aquanaut may develop new kinds of sleep requirements which differ from those of land based man, (2) whether man may also develop serious sleep disturbances, whether we can specify the optimal physical and psychological conditions for man's recuperation from fatigue by adequate sleep in the underwater habitat.

TEKTITE I, a nitrogen saturation diving experiment is used to illustrate an attempt to obtain the data necessary to define sleep requirements of man-in-the-sea.

290. Narinskaia A. L. (1977). Dynamics of the human mental work capacity during some activity regimes. (Dinamika Psikhicheskoi rabotosposobnostichelovека pri nekotorykh rezhimakh deiatel'nosti). In: Optimization of the professional activity of a cosmonaut. (pp. 109-120). Moscow: Izdatel'stvo Nauka. (In Russian) (NASA No. A78-13584).

Experimental studies of the dynamics and characteristics of human mental work capacity during some activity regimes are described. The regimes were: 72 hours awake; 45 days with the daily sleep-wakefulness rhythm reversed (that is, shifted by 12 hours); 25 days with 72 hour periods of wakefulness as well as reversal of the daily sleep-wakefulness rhythm; and 16 hour diurnal periods. The possibility of restructuring the diurnal dynamics of some mental functions was demonstrated, and indices of mental work capacity were used to determine the adaptation period to new diurnal regimes.

291. Neel S. (1973). Aviation medicine. In: Medical support of the US Army in Vietnam 1965-1970. (pp. 99-107). Washington, DC: Department of the Army.

This chapter reviews the medical care given to US Army aviators in Vietnam from 1965 to 1970. The duties of the flight surgeons assigned to aviation companies are reviewed; along with a description of the flight care program instituted in Vietnam, attention is given to the problem of flyer fatigue. Several methods used to combat fatigue are reviewed. The author concludes that total flight hour limits are somewhat less than effective in limiting fatigue in a combat environment, but cites the "goal directed" flying hour schedule used by the 269th Aviation Company as being both workable and effective. This system would schedule a pilot for 5 to 6 days of flight operations and then schedule a day free from all duties. Also, problems of fatigue for enlisted crewmembers and flight support personnel are addressed.

292. Neff K. L., & Solick R. E. (1983). Military experts' estimates of continuous operations performance (Or close but no cigar). (USARI Report No. TR-600). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD A140-220).

The feasibility of supplementing human performance data with estimates of performance in adverse environments was examined for cases where no hard data are available for use in land combat models. The accuracy of military experts' estimates of performance in continuous operations was evaluated by examining the amount of convergence between samples of estimates made by military officers and actual performance values obtained in four field exercises. There was strong

agreement among the officers in their predictions of performance. However, the officers' predictions of performance did not agree with actual performance measures obtained in the field exercises.

293. Nicholson, A. N. (1970). Influence of duty hours on sleep patterns in aircrew operating in the long haul transport role: A study of single crew operations and double crew continuous flying operations. In A. J. Benson (Ed.), Rest and activity cycles for the maintenance of efficiency of personnel concerned with military flight operations. Proceedings of NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Oslo, Norway. (NATO/AGARD Report No. CP-74-70). London: Technical Editing and Reproduction Ltd.

Military aircrew operating in the strategic long haul role experience repeated time zone changes and irregular and often long hours of duty. A satisfactory sleep pattern is of prime importance in maintaining their well-being and operational efficiency. The normal regular nightly period of sleep during non-flying duty at base is replaced by complex sleep patterns while operating world-wide east-west routes. However, the sleep obtained over three days preceeding each duty period is usually similar in duration to that obtained over three day periods while on non-flying duty and the ability of the pilot to obtain a similar amount of sleep appears to be an essential factor in preventing subjective fatigue.

There is a cumulative effect of repeated adaptation to time zones and irregular hours of duty. Aircrew find it increasingly difficult to maintain an acceptable sleep pattern as the number of days of route flying increase. It appears that the workload (average hours duty/day) compatible with an acceptable sleep pattern diminishes in a logarithmic manner with the number of duty days. This implies restrictions to the deployment of aircrew if serious sleep disturbances are to be avoided.

To increase the effectiveness of a strategic transport force in the absence of positioned crews, double crew continuous flying operations were studied. In these missions the off-duty crew rests within the aircraft. The success of such operations depends to a large extent on the crew which operates during the period in which they are normally accustomed to sleep.

From experience within the Royal Air Force Air Support Command the optimum duration of such a mission is about 48 hours. Beyond this period serious sleep disturbances appear. An operation of 48 hours using a fast strategic transport provides a world-wide capability and during this time the

aircraft can circumnavigate the world.

294. Nicholson A. N. (1970). Military implications of sleep patterns in transport aircrew. Proceedings of the Royal Society of Medicine, 63, 570-572.

The Royal Air Force Institute of Aviation Medicine and the Board of Trade Civil Aviation Medical Department conducted studies of flight deck environments of both military and civil transport operations. These studies reported that operating long haul routes can grossly affect aircrew sleep/work cycles. These studies have helped to formulate the manner in which aircrew sleep is modified and to define the workload compatible with a sleep pattern which approximates in some respects to that experienced during nonflying duty.

295. Nicholson A. N. (1970). Sleep patterns of an airline pilot operating world-wide east-west routes. Aerospace Medicine, 41, 626-632.

The sleep patterns of an airline pilot operating long haul east-west routes have been observed over a period of 18 months The normal sleep pattern was modified by irregular duty periods and by adaptation to time zone change. Sleep disturbance rather than sleep deprivation is the main problem in such aircrew. The physiological significance of the sleep patterns experienced during route flying is not understood, but it appears possible that complex adjustments of intrasleep cycles and short periods of sleep (naps) may provide an adequate sleep pattern.

296. Nicholson A. N. (1972). Duty hours and sleep patterns in aircrew operating world-wide routes. Aerospace Medicine 43, 138-141.

Sleep patterns of an airline pilot operating worldwide, east-west routes have been related to duty hours. Duty hours compatible with an acceptable sleep pattern may be related in a logarithmic manner with the number of days of the schedule. It appears that the most critical consideration in preserving a control sleep pattern may involve the relation between total duty hours and duration of schedule.

297. Nicholson A. N. (1972). Rest and activity patterns for prolonged extraterrestrial missions. Aerospace Medicine 43, 253-257.

Difficulties in obtaining satisfactory sleep have been encountered during many space missions and it is generally recognized that an appropriate rest and activity pattern is essential to maintain the well-being and operational

effectiveness of spacecrews. During earth orbital flights and lunar explorations, satisfactory sleep is more likely if the crews maintain a reasonable relation with their normal terrestrial rhythm. But many missions have required unusual patterns of activity. In the future, prolonged extra-terrestrial flights may also demand that the sequence of work and rest be subordinated to operational requirements and under these circumstances work and rest regimes developed under earth conditions may be of little use.

Irregular duty periods superimposed upon daily cycles of varying duration are experienced by long haul transport aircrew and an analysis of these schedules has suggested that irregular patterns of rest are compatible with a satisfactory sleep pattern as long as the workload is limited. A similar relationship could be established for prolonged spaceflights and in this context the sleep patterns of an airline pilot operating worldwide schedules have been examined and relevant recent work on modified sleep regimes discussed.

298. Nicholson A. N. (1978). Irregular work and rest. In G. Dhenin (Ed.). Aviation Medicine, Vol 1: Physiology and Human Factors. (pp. 494-503). London: Tri-Med Books Limited.

This textbook chapter provides a brief review of the problems of disturbed sleep and circadian function in air operations and attempts to outline current approaches to the many important issues involved in the management of irregular rest and activity. A comparison of sleep patterns of long-haul and short-haul aircrews reveals that long-haul crews typically make use of short "naps" to obtain adequate amounts of sleep while short-haul crews choose instead to prolong some regular sleep periods to compensate for sleep deprivation. Shifts in circadian activity and their effects on performance are outlined. Also, a function for determining optimum and maximum duty hours is presented to assist the flight crew's doctor in determining adequate and excessive workload schedules. The use of hypnotics to aid in inducing sleep in pilots is discussed.

299. Nicholson A.N. (Ed.). (1979). Sleep, wakefulness and circadian rhythms. (NATO/AGARD LS No. 105). NATO Advisory Group for Aerospace R&D Lecture Series. London, England: Technical Editing and Reproduction Ltd.

The lecture series is intended for those concerned with the management of civil, and particularly military personnel, who have to cope with irregular work and rest. It will provide an understanding of the physiological processes involved in the adaptation of man to disturbed sleep and wakefulness, and consider approaches to the problem of management including the use of drugs.

The lectures presented in this volume are on three subjects: 1)sleep, wakefulness and circadian rhythms: the physiological and psychological aspects; 2)adaptation of man to disturbed sleep and circadian rhythmicity; and 3) management of irregular rest and activity.

300. Nicholson A. N. (1983). Hypnotics and air operations. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338, pp. 15-1 to 15-8). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-989).

Personnel engaged in transport operations may use drugs for a specific medical condition or for purposes which are related to the nature of their occupation. Examples of the former are drugs in the management of hypertension and antihistamines in the treatment of allergic states, while examples of the latter are drugs in the prophylaxis of malaria and hypnotics in the management of disturbances of sleep. Unfortunately many drugs have central effects and centrally acting drugs may have persistent activity, and so careful attention must be given to the advantages of a drug and its possible adverse effects on performance.

The factors which influence the use of a drug in the context of occupational medicine vary. The author discusses the use of hypnotics and antihistamines as they raise two very different issues. In the management of sleep disturbance the challenge is to provide an effective hypnotic free of adverse effects on sleep and of residual effects on performance, whereas with the allergic states the individual must remain alert while the drug is acting peripherally. This paper deals with hypnotics.

301. Nicholson A. N., Borland R. G., & Stone B. M. (1979). Hypnotics and the management of disturbed sleep. In: A.N. Nicholson (Ed.). Sleep, wakefulness and circadian rhythm. (NATO/AGRAD Report No. LS-105 pp 12-1 - 12-11). London: Technical Editing and Reproduction Ltd. (DTIC No. AD A075-240)

The article reviews research on performance and sleep to include sleep during the day. A brief description of the methodologies used in type of research and review of research using Barbiturates, Benzodiazepines, Diazepam and its hydroxylated metabolities, Nordiazepam and its precursor, potassium clorazepate, and studies on sleep as the investigative drug are included.

It is evident from these studies carried out in healthy men, that some guidelines can now be given for the occasional use of hypnotics in the management of sleep when impaired performance the next day would be unacceptable. The prolonged effect of nordiazepam and potassium clorazepate would suggest that these compounds are more appropriate in the management of insomnia secondary to anxiety, in which a persistent day-time anxiolytic effect with minimal effects on performance is required, while diazepam and its hydroxylated metabolites, temazepam and oxazepam, are appropriate in the management of disturbed sleep when a residual effect during the day after overnight ingestion is to be avoided.

However, there are certain points which should be taken into consideration in the use of hypnotics. With daily ingestion of diazepam (5-10 mg), its long-acting metabolite, nordiazepam, could accumulate, and so the dose of diazepam should not only be kept within 10 mg as residual effects are observed above this range, but it should not be repeated at intervals of less than 48 h or given more than twice in seven days. Diazepam would appear to be particularly useful for sleep at unusual times of the day. Oxazepam (15-30 mg) is also without residual effects, but the relatively slow absorption of the drug, and the lack of effect on sleep onset latencies may reduce its usefulness, though otherwise it is an effective hypnotic. Temazepam (10-20 mg) has a useful hypnotic effect, and, like oxazepam, as the advantage that its metabolism is not complicated by a long-acting metabolite, and so daily ingestion is unlikely to be contraindicated.

However, it is important to stress, as with all hypnotics, that it is the individual response of each recipient which is paramount, particularly if they are involved in skilled activity.

302. Nicholson A. N., Pascoe P. A., Roehrs T., Roth T., Spencer M. B., Stone B. M., & Zorick F. (1985). Sustained performance with short evening and morning sleeps. <u>Aviation, Space, and Environmental Medicine</u>, <u>56</u>, 105-14.

The effect which early evening sleep may have on overnight and subsequent daytime performance, and the effect which morning sleep may have on daytime performance after overnight sleep deprivation has been studied in six healthy male volunteers. It would appear that relatively short periods of natural and drug induced (brotizolam 0.125 mg) sleep have a beneficial effect on subsquent performance even in the absence of preceding sleep debt. In the event of disturbed sleep in shift-work a hypnotic may be helpful, and in this context, one which is rapidly eliminated and sustains sleep is appropriate.

303. Nicholson A. N., & Stone B. M. (1982). Sleep and wakefulness handbook for flight medical officers. (NATO AGARDograph No. AG-270 (E)). A NATO Advisory Group for Aerospace R&D Aerospace Medical Panel publication. London, England: Technical Editing and Reproduction, Ltd.

The inevitable irregularity of work in aircrew is of concern to both civil and military operations, and this handbook is intended for flight medical officers. The relation between alertness and sleep, the nature of sleep in man and his circadian rhythmicity are described, and these factors are discussed in the setting of shiftwork, transmeridian flight and air operations. Disorders of sleep and arousal as they may involve the aeromedical specialist are also covered, and the use of hypnotics discussed.

304. Nicholson A. N., Stone B. M., Borland R. G., & Spencer M. B. (1983). Adaptation to irregularity of rest and activity. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338, pp. 12-1 to 12-6). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-987).

Adaptation to conventional shiftwork has been the subject of considerable research , but there is little information on the effect of irregular work and rest which is usually a feature of air operations. Under such circumstances the circadian rhythmicity of the individual and changes in the quality of sleep, as well as the duration of each work period, are likely to influence effectiveness at any given time. The study reported here was carried out to evaluate the influence of these factors.

The schedule of work and rest involved twenty-four 6-hr periods of work and twelve 6-hr periods of rest over 9 days. It was preceded and followed by 2 days of normal nycthemeral activity. It was the intention to study irregularity of sleep and to avoid serious sleep deprivation, so an average of 8 hrs rest was provided every 24 hrs.

Sleep onset latency did not differ from that of the control night throughout the schedule, but total sleep time was reduced markedly when sleep commenced during the day and when the period of prior wakefulness did not exceed 16 hours. Total sleep time was correlated with the length of prior wakefulness for each subject and for the group.

O

305. O'Donnell R. D. (1983). The US Air Force neurophysiological workload test battery: Concept and validation. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338, pp. 5-1 to 5-10). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-982).

In assessing the workload effects of sustained operations, it is likely that a multistage process must be employed. Broadly based measures such as timeline analyses and subjective estimates are used to identify specific problem areas in a given sustained operation. These workload "choke-points" are to be intensively studied using a variety of subjective, behavioral, and physiological measures to tap the appropriate resources within the individual and to provide an estimate of how these resource demands interact with task demands and response variables.

The U.S. Air Force Aerospace Medical Research Laboratory is developing workload metrics spanning the entire spectrum, from task analysis through subjective and behavioral measures. In addition, neurophysiological measures have been investigated for a number of years with respect to their sensitivity in assessing workload. As a result of these studies, a test battery consisting of six different electrophysiological measures in eleven different forms was constructed. These six tests were selected because they each measure one aspect of workload practiced in applied settings.

This test battery is undergoing validation studies in simulator environments and successfully validated tests will be incorporated into a second generation neurophysiological test battery to be used in field workload assessment. This paper details the overall rationale of the tests selected, as well as presenting some of the experimental evidence supprting their use as workload assessment devices. Current validation studies and plans for future test modifications are also presented.

306. O'Donnell R. D., Bollinger R., & Hartman B. O. (1974). The effects of extended missions on the performance on airborne command and control teams: A field survey. (USAF AMRL Report No. TR-74-20). Wright-Patterson Air Force Base, OH: US Air Force Aerospace Medical Research Laboratory. (DTIC No. AD A011-549).

This report covers the effects of extended mission lengths on the performance of airborne command and control teams, wherein complex "cognitive" components consisting primarily of information collection, interpretation, and communication constitute the bulk of workload. The survey centers on investigating general categories of performance-related factors, such as overall fatigue, rather than specific task performances such as long-term memory, sensory motor reaction time, or information processing.

307. O'Donnell R. D., & Eggemeier T. F. (1983). Conceptual framework for the development of workload metrics in sustained operations. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO/AGARD Report No. CP-338, pp. 4-1 to 4-10). Loughton, Essex, United Kingdom: United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-981).

In sustained operations, the cumulative effect of workload may lead to unpredicted, catastrophic human failure. Workload assessment, has suffered from the lack of an overall, standardized framework to permit development of sensitive, predictive metrics. Such a general framework is developed in this paper, based on the view that workload is a multiply-determined hypothetical construct conveniently summarizing the interactions which limit task performance. Major task, operator, and response factors are presented, and related to metrics available or being developed for assessing these factors. The framework is then used to suggest the broad outlines of a research program leading to standardization of workload assessment in sustained operations environments.

308. Opstad P. K., Ekanger R., Nummestad M., & Raabe N. (1978). Performance, mood, and clinical symptoms in men exposed to prolonged, severe physical work and sleep deprivation. Aviation Space and Environmental Medicine, 49(9), 1065-1073.

Fourty-four young men participated in strenous combat courses of 4 days (course I) or 5 days (course II), almost without sleep. They were tested and examined clinically each morning. Groups 1 and 2 had no organized sleep, whereas groups

3 and 4 got 3 and 6 h, respectively, in the middle of each course. Substantial impairment was observed in all tests, as well as clinical symptoms toward the end of the courses for groups 1 and 2. In the vigilance test, the reaction time task, the coding test, and the profile of mood-state, significant impairment was observed even after 24 h. Complaints of symptoms came first. Disturbance of senses and behavior appeared later. Group 4 had significantly better results than groups 1 and 2 in clinical symptoms and all tests, except the positive score in mood-state. Group 3 occupied an intermediate position. Corresponding results were obtained in the two separate courses. In the morning following the course, recovery after 4 h of sleep was less extensive for course II than course I participants.

309. Orr W. C., Hoffman H. J., & Hegge F. W. (1976). The assessment of time-dependent changes in human performance. Chronobiologia, 3(4), pp. 291-305.

The assessement of human performance and performance decrement presents numerous problems, particularly when questions concerning causal factors are considered. The situation becomes particularly acute when continuous performance is the primary investigative interest. Time then becomes an undeniable independent and dependent variable that permeates every aspect of the experimentation.

Time, as a variable, presents formidable analytic difficulties. Any analysis beyond the most elementary descriptive statistics requires techniques that are not part of the standard psychological or biological analytic armament. Thus, in order to properly analyze data collected over time, time series analysis represents the method of choice. Several analytic Techniques which have been used to decribe circadian and ultradian rhythms in human performance are: least square analysis, spectrum analysis, and complex demodulation. Results from spectrum analysis and complex demodulation are emphasized.

This paper describes a series of experiments to illustrate the use of various methods of time series analysis in the delineation of the effects of circadian and ultradian cycles on human performance. These experiments are concerned with measures of both human performance and physiology. They illustrate how the parameters of these time series analytic techniques can be used to postulate physiological mechanisms where time-dependent changes have been shown to be significant. The use of analytic in both the time and frequency domain is illustrated.

310. Oser H., & Wegmann H. M. (1974). The catecholamine and 17-hydroxycorticoid excretion of five aquanauts during their stay in the underwaterlaboratory "Tektite II." (DLR Report No. FB 74-02). Bonn-Bad Godesberg, Germany: Deutsche Forschungs-und Versuchsanstalt fur Luff-und Raumfahrt.

Studies on five aquanauts of the U.S. underwater laboratory "Tektite II" were performed during their 14-day-stay in a high pressure environment by analyzing the urinary excretion of catecholamines and 17-hydroxycorticosteroids (17-OHCS). The results showed a distinct increase of both the catecholamines and the 17-OHCS. Though the rhythm of life was shifted, the excretion of noradrenaline and 17-OHCS showed a stable circadian pattern whereas adrenaline was shifted by about 8 hours towards the night. The increased excretion rates indicate a stress situation caused by many dives and life in an underwater habitat.

P

311. Patrol ASW Development Group. (1970). Problems of fatigue in patrol aircrewmen during extended flight operations. (ASW Report No. TR 33). Norfolk, VA: US Naval Air Station. (DTIC No. AD 509-163L).

During a forty day period in 1969, a patrol squadron in a P-3 aircraft operated with the various demands of an extended Anti-Submarine Warfare exercise in passively tracking an assigned nuclear submarine target. The purpose of this portion of the project was to obtain information from the flight personnel regarding the fatigue they may have experienced during the extended exercise. The five crews which had the most overall flight time were selected for this study. A questionnaire was given to all crewmembers. The squadron commander, executive officer and flight surgeon at the time of the operation were interviewed as well as one officer from each of the five crews.

The areas studied included brief/debrief times, activity during transit periods, workload prior to and during the flight, tactical effectiveness, safety, quality of operating bases, rest and sleep, illness, boredom/monotony, superior's interest, motivation and morale throughout the exercise. Conclusions were drawn relating the above areas to the occurrence of fatigue. Recommendations were made in the areas of flight hours, augmentation of maintenance and ground support personnel, crew work/rest schedules, and cross-training.

312. Pegram V., Storm W., Hartman B. O., Harris D. A., & Hale H. B. (1970). Evaluation of sleep, performance and physiological responses to prolonged double crew flights: C-5 operation Cold Shoulder, a preliminary report. In A. J. Benson (Ed.), Rest and activity cycles for the maintenance of efficiency of personnel concerned with military flight operations. Proceedings of the NATO Advisory Group for Aerospace R & D (AGARD) Aerospace Medical Panel Specialists' Meeting at Oslo, Norway. (NATO/AGARD Report No. CP-74-70). London: Technical Editing and Reproduction, Ltd.

"Cold Shoulder" was a real-world experiment designed to determine the effects on aircrewmen of marrying two crews to a jet transport and flying operational missions. Two basic crews

were flown in a C-141 cargo aircraft, using either a 4/4 or 16/16 hours work/rest cycle. A battery of measures was collected on each crew: (a) oral temperature, (b) endocrine-metabolic trends, (c) electroencephalogram (EEG) for determining sleep, and (d) crew performance evaluations. The oral temperature data showed that flight per se induced a low-grade hypothermia which was more pronounced in individuals occupying key crew positions. The endocrinemetabolic data tentatively suggested that the aircraft commanders, as a group, experienced more stress than the other crewmembers. The sleep EEG analysis showed that both human and primate subjects suffer a significant reduction in deep sleep and dream sleep when exposed to actual or simulated flight conditions. When combined with the sleep and physiological changes, the performance data from both humans and primates suggests caution in the application of in-flight double crews.

3'3. Perelli L. P. (1980). Effects of fatigue stressors on flying performance, information processing, subjective fatigue, and physiological cost indices during simulated, long-duration flight. (Dissertation Abstracts). Washington, DC: The Catholic University of America.

The purpose of this study was to assist in the development of flight duration parameters for scheduling aircrew workrest cycles. This was achieved using objective measures of flying performance, subjective reports of fatigue and sleepiness, and three physiological indicators: Heart Rate (HR), Heart Rate Variability (HRV), and Rectal Temperature. An additional purpose was to demonstrate the correlation among these measures and relate them to a Discrete Information Processing Test (DIPT) developed for eventual use in the actual flight environment.

The DIPT is a computer-controlled, 5-choice reaction time task which adapts its stimulus presentation rate to the subject's response accuracy and continuity, up to a point where the subject can no longer keep pace. Through an iterative process, the subject's threshold of information processing speed can be determined.

A literature review of fatigue evaluates past research concerning performance decrement accompanying sleep deprivation, physiological cost indices of fatigue, circadian rhythm changes, and flying skill assessment. The unique requirements for a device to assess performance in the field are discussed and presented as the rationale for the development of the DIPT. The DIPT is described within the framework of adaptive technology.

It was hypothesized that each dependent measure would

change significantly in the presence of three fatigue stressors experienced during simulated flight: (a) time awake prior to flying (1 vs 12 hours), (b) daily flight duration (9 hours), and (c) total mission duration (4 days).

Twenty-four airmen each received an intensive 7-day flight training program in Link Fixed Wing Flight Trainers. Then, 12 subjects followed a schedule that regularly alternated 12-hour duty days with 12-hour crew rest periods for 4 days. The remaining subjects followed a schedule with duty days of 12, 24, 24, and 12 hours, each separated by a 12-hour crew rest period. During each duty day, all subjects flew two 4.5-hour simulated flights, separated by a 1-hour rest.

Flying performance was evaluated by a time-on target tracking score derived from heading, altitude, airspeed, turn rate, turn coordination, and vertical velocity errors. PDP-12 computer administered and scored both a simple straight and level test, a complex flight maneuver test, and the DIPT, each flight hour. Continuous HR and Rectal Temperature, subjective fatigue and sleepiness reports, and sleep logs were collected throughout each mission.

All measures demonstrated significant fatigue effect. HR increased with flight task complexity only during extreme fatigue. HRV decreased with increasing task complexity for both groups, for all three performance measures. Performance on the less complex flight task declined most during extreme fatigue. Disrupted circadian rhythm during night flights seemed to cause greater performance decrement than cumulative fatigue. Performance measures, subjective fatigue, and sleepiness reports were significantly correlated with each other and to changes in Rectal Temperature. Subjects recovered from the intense fatigue effects by the fourth flight day.

314. Perelli L. P. (1980). Fatigue stressors in simulated long-duration flight. Effects on performance, information processing, subjective fatigue, and physiological cost. (USAF SAM Report No. TR-80-49). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A105-484/0).

The purpose of this study was to assist in the development of flight duration parameters for scheduling aircrew work-rest cycles. Twenty-four Airmen were selected to represent the USAF pilot population on the basis of flight aptitude scores, class II flight physicals, and personal interviews. Each participated in an intensive 7-day flight program in Link GAT-1 Trainers. Then half of the subjects were randomly assigned to a schedule that regularly alternated 12-hr duty days with 12-hr rest periods for 4 days. The remaining subjects followed a schedule with duty days of 12, 24, and 12 hr, with a 12-hr rest

period between duty days.

During each duty day, all subjects flew two 4.5-hr simulated flights. Flying performance was evaluated every hour by both simple and complex flight maneuver tests, administered and scored by a PDP-12 computer. The subject's threshold of information processing speed was determined hourly by a Discrete Information Processing Test (DIPT). (The DIPT is an adaptive, computer-controlled task developed for eventual use in the actual flight environment.). Continuous heart rate (HR), heart rate variability (HRV), fatigue, sleepiness scores, and sleep logs were collected throughout each mission. Results are presented in the report.

315. Perry I. C., (Ed.). (1974). Helicopter aircrew fatigue. (NATO/AGARD Report No. 69). London: Technical Editing and Reproductiion, Ltd. (DTIC No. AD 780-606).

Studies by the NATO AGARD Aerospace Medical Panel have shown that aviator fatigue is generally agreed to be an important problem in helicopter operation. Apart from the effects that such a condition has on efficiency, fatigue has also been found to be an important contributory factor in helicopter accidents, both in peace time operations and in the combat environment. Many of the major causes of fatigue result from inadequate training on the part of those responsible for the well-being of aircrew. Such training in the causes and effects of fatigue would of themselves lead to the changes of organization and procedures which would minimize the occurrence of fatigue.

It has been found that the Army helicopter aviator throughout the NATO nations, continues to be treated and to work under the same conditions as the ground soldier. While such a policy may have been desirable in the past, it can now be argued that because of the increasing complexity and expense of the aircraft used, the helicopter aviator should be considered as more of an integral part of the man-machine complex rather than as a ground soldier. He should therefore be managed and maintained more like the aircrew of the Air Forces and Navies of NATO.

The report contains a rank order listing of items which 500 helicopter aircrew members rated as being important contributors to pilot fatigue. A comparison of actual flying hours and rest period standards for helicopter pilots in NATO nations is also presented.

316. Petersen P. B. (1972). Fatigue in sustained tactical operations. (USACDC Technical Report). San Antonio, TX: US Army Medical Service Agency, Combat Developments Command. (DTIC No. AD 746-643).

Concepts for future US tactical operations envision man's capabilities as encompassing rapid acclamation, fatigue reduction, changed wake-sleep cycles, and changes to the circadian cycles under sustained and continuous operational requirements. Our forces must be able to compete with and win against an enemy who may have these capabilities. No evidence can be found of any current coordinated effort to collect, evaluate or recommend measures that can be used in the study sub-areas.

This study focuses on concepts for the reduction of fatigue in its various stages in sustained tactical operations. There are a number of concepts applicable for this subject, yet, fatigue reduction by chemical and electronic methods are assumed not be politically and socially feasible and hence are not dealt with in this paper. Methods for the reduction of fatigue focus specifically on techniques of leadership and on measures to prevent fatigue as well as measures taken to reduce the effects of fatigue, once it is evident. In addition, other subject areas within the scope of fatigue reduction are isolated in terms of areas that need to be identified for further research in order that factual conclusive information can be recommended for use in tactical training.

317. Pfeiffer M. G., Siegel A. I., Taylor S. E., & Shuler L. (1979). Background data for the human performance in continuous operations guidelines. (USARI Report No. 386). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

This report presents the technical data and literature review necessary to develop a companion volume to a handbook: Human Performance in Continuous Operations Guidelines. The literature relates to the effects on individual performance of the stressors associated with continuous Army operations. Critical tasks associated with a typical continuous operation are identified along with the results of a study into the influence of various continuous operation stressors on performance effectiveness. Needed research into the effects of various continuous operations stressors on soldier performance is described.

318. Pleban R. J., Thomas D. A., & Thompson H. L. (1985). Physical fitness as moderator of cognitive work capacity and fatigue onset under sustained combat-like operations. Behavior Research Methods, Instruments & Computers, 17, 1, 86-89. (ARI Tech Report No. In press). Fort Benning, GA: US Army Research Institute for the Behavioral and Social Sciences, Fort Benning Field Unit.

A study was devised to investigate the role of physical fitness in moderating both cognitive work capacity and fatigue onset under sustained combat operations. Sixteen male ROTC cadets were followed through a two and a half-day Pre Ranger Evaluation exercise. Prior to the actual start of the exercise the cadets' overall level of physical fitness was assessed by using five fitness indices (Harvard Step Test, chinups, pushups, situps, and two-mile run). Cognitive performance and subjective measures of fatigue state were assessed at regular intervals before, during, and one day after the exercise. The results suggest that fitness may attenuate decrements in cognitive work capacity for certain tasks requiring prolonged mental effort, particularly as the cumulative effects of sleep loss and other stressors begin to mount. Similarly, the results of this study suggest that as overall stress levels increase, fitness may have a beneficial effect in moderating fatigue rate. Fitness did not significantly enhance the recovery process with respect to cognitive work capacity, and actually appeared to hinder recovery from fatigue.

319. Polzella D. J. (1974). The effect of sleep-deprivation on short-term recognition memory. (USAF OSR Report No. TR-74-329). Ann Arbor, MI: Univeristy of Michigan, Human Performance Center. (DTIC No. AD 784-895).

A multitrial probe-recognition experiment was conducted using five male subjects under normal conditions and under conditions of 24-hour sleep-deprivation. Results indicated a predicted decrement in short-term recognition memory following sleep loss due to the increased incidence of lapses, periods or lowered reactive capacity, which apparently prevented the encoding of to-be-recognized items.

320. Poulton E. C. (1972). The effects of fatigue upon sonar detection. (MRC NPRC Report No. OES 20-72). London, England: Royal Naval Personnel Research Committee. (DTIC No. AD A013-124).

Many vigilance experiments are not very relevant to sonar work. The most relevant experiments are listed in this report. In most experiments vigilance declines during the watch, even after fairly prolonged practice at the task.

The decline in vigilance can be prevented if identical artificial signals are injected when there are no real signals, and full knowledge of results is given on the artificial signals. Another method of maintaining vigilance is to provide the sonar monitor the assistance of a computer. If desired the computer can be programmed to inject artificial signals, and give knowledge of results on them, when it detects no true signals.

The article presents a list of the effects of mild stresses upon vigilance. A sleep debt of about 5 hours reduces vigilance. With enlisted men, vigilance is low at the start of the working day and after a heavy meal. A cabin which is too warm for comfort may help to increase vigilance. So may extraneous noises.

321. Poulton, E.C., Edwards, R.S. & Colquhoun, W.P. (1971). Efficiency in heat after a night without sleep. (MRC NPRC Report No. OES 8-72). London, England: Royal Naval Personnel Research Committee. (DTIC no. AD 763-040).

Mild heat is a behavioral arouser. It can help to counteract the effect of loss of sleep for short periods of time. But mild heat also degrades performance. So it should not be used deliberately to counteract the effects of sleep loss.

322. Preston F. S. (1970). Time zone disruption and sleep pattern in pilots. Transactions of the Society of Occupational Medicine, 20, 77-86.

This study investigated sleep patterns in BOAC pilots by having them keep a log of sleep time and subjective feelings of tiredness or freshness on retiring to bed. Much more research is required in this field--the control of plasma cortisol levels being possibly the most promising. In addition, the control of external cues such as illumination/darkness could also be investigated in the transport field. This could probably be accomplished by removing aircraft windows and transportating the unfortunate passengers in total darkness. This would not be a popular airline. In the case of airline operating crews, the problem is more acute. The economic pressures on airlines to operate their aircraft throughout the twenty-four hour period are immense. One way of tackling the problem would be to base crews down the routes. By so doing the pilots would operate over set routes with small time-zone changes; but the costs involved on overseas bases are considerable and although popular with the individual pilots and their families, the system has led in the past to trade union disagreements.

An alternative method, used in some long-haul U.S. airlines, is to send the crew round the world at a much faster rate, i.e., 6-8 days. In this way, by keeping stop-overs between 14-24 hours, pilots manage to remain on their home time throughout the trip, e.g., Eastern Standard Time if operating out of New York and Pacific time if operating out of San Francisco. Such a regime, while rigid, is based on good physiological principles and pilots get their tours over and return to their homes with a minimum of delay. To achieve such a regime, of course, demands a highly professional outlook by the pilots backed by good hotels which can provide the sort of service described in this article.

323. Preston F. S. (1973). Further sleep problems airline pilots on worldwide schedules. <u>Aerospace Medicine</u>, <u>44</u>, 775-782.

This study follows previous work carried out on airline pilots operating long-haul transmeridian routes with particular respect to the sleep patterns obtained at slip stations en route. The author accompanied a B-707 crew on a long transmeridian tour when all members kept careful sleep logs of 1 month. The data obtained show clear evidence of sleep deficit occurring in tours of this nature with some evidence of age variation in individuals. The practical problems in scheduling crews in such operations are discussed in some detail in relation to performance, the use of hypnotics, and difficulties surrounding pilots in bidding for successive tours which may result in sleep deprivation.

R

324. Radloff R. & Helmreich R. (1968). Groups under stress: Psychological research in Sealab II. New York: Appleton-Century-Crofts.

SEALAB II was a R and D project sponsored by the Office of Naval Research and the Special Projects Office of the US Navy. Its purpose was to open up the millions of square miles of submerged territory comprising the continental shelves by showing that man can live in this environment and perform useful work for extended periods without returning to the surface.

Three 10-man teams composed of civilian and military divers, scientists and salvage specialists lived and worked in a habitat 205 feet under the sea for periods of time extending 15, and in once case 31, days. During their stay under the sea the aquanauts worked on such tasks as salvaging a sunken jet airplane, conducting censuses of marine life, studying current, water temperature and visibility, experimenting with underwater acoustics, evaluating the effectiveness of a trained porpoise and testing a wide range of experimental equipment.

Additionally, the aquanauts served as subjects for both physiological and psychological research. The attempt was to see how well a man could work under uater while living there.

Long hours of work , combined with difficulties in sleeping produced extreme fatigue in many of the aquanauts. Difficulties in sleeping were caused by the exotic atmosphere, the need for standing around the clock watches in order to monitor the gas and electrical equipment, and probably also in part by high arousal from the multitude of stressful stimuli. Nearly all of the divers stated that they became very tired by the end of their fifteen day stay.

This book describes the measures and observations collected during this historic research project, with a special emphasis on the psychological and physiclogical responses to the obviously stressful working and living situation.

325. Ray F. T., Martin O. E., & Alluisi E. A. (1960). Human performance as a function of the work-cycles: A review of selected studies. (NRC Pub. No. 882). Washington, DC: National Academy of Sciences, National Research Council. (DTIC No. AD 256-313).

Studies relating the effects of different work-rest cycles on man's performance are reviewed. Included are only those studies in which (a) observations of performance extend for 24 hours or longer, and (b) results pertain to the general problem of optimizing performance through the scheduling of work and rest periods.

While several specific conclusions are supported by the studies reviewed, the number of generalizations relating to optimal work-rest scheduling are limited. It is not yet possible to describe accurately the complex relations among performance variables, work-rest cycles, sleep-wakefulness cycles, and the durations of the work, rest, and sleep periods. The need for additional long-term experimentation is evident.

326. Riemersma J. B. J., Sanders A. F., Wildervanck C., & Gaullard A. W. (1976). Performance decrement during prolonged night driving. (Report No. IZF-76-14, TDCK-68563). Conference presented at the NATO Symposium on Vigilance 2: Relationships among Theory, Physiological Correlations and Operational Performance, at St. Vincent, Italy, August 1976. London: Technical Editing and Reproduction Ltd.

In an attempt to demonstrate progressive performance decrement, an exploratory experiment was carried out in which the effects of long-term work, declining diurnal rhythm, and accumulating sleep loss converge. Subjects carried out a continuous driving task between 6 and 22 hours, preceded and followed by two driving tests of 45 minutes each. In another condition they had only the pre- and post-test and slept in between.

The results show progressive decrements of performance on several performance measures, including lane drifting and two subsidiary tasks. In general, considerable recovery was observed in the post-test. Although heart rate declined and heart rate variability increased during the long nightly spell, there are strong arguments against relating heart-rate and fatigue. Suggestions for future research are discussed.

327. Robson B.M., Huddleston H. F., & Adams A. H. (1974). Some effects of disturbed sleep on a simulated flying task. (RAE Report No. TR-74-57). Farnborough, England: Royal Aircraft Establishment. (DTIC No. AD 923-598).

Data are reported for 12 Royal Air Force pilots required to perform a series of 30-minute runs in a simple flight task simulator. Six pilots knew they were to return to bed immediately after a 0300 (or 0330) hour run, and six knew they were to remain awake and work. Pilots aroused for a single early morning task showed degraded altitude control performance, scored significantly higher on a subjective fatigue check list, and recorded a larger number of fast reaction times to peripheral lights.

328. Rokicki S. M. (1982). Fatigue, workload, and personality indicies of traffic controller stress during an aircraft surge exercise. (USAF SAM Report No. TR-82-31). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A121-908/8).

During an aircraft surge recovery exercise, stress survey instruments were administered to 25 USAF air traffic controllers. The survey instruments consisted of sleep reports, fatigue and workload scores, and the State-Trait Personality Inventory (STPI). The STPI yields scores to measure anxiety, curiosity, and anger. Data were collected for a 4-day period during the exercise, with a maximum of 22 controllers participating on any single day. The data were collected to provide a baseline for comparison with future studies involving chemical warfare defense equipment.

Although the controllers averaged more than 7 hours sleep per night during the exercise period, 70% felt they could have used more sleep. The average subjective fatigue level never suggested more than moderate fatigue. The average perceived workload corresponded to a challenging but manageable level. Average State scores for anxiety, curiosity, and anger were generally low; average Trait scores for these same emotions were below scores reported for Navy recruits and college freshmen. During the course of the exercise, significant differences were found in State anxiety scores, as the novel situation (the exercise) became a familiar routine. The major conclusion is that the surge recovery exercise, in comparison to normal duty conditions, had minimal effect on all measures for this group of controllers.

329. Rosa R. R., Wheeler D. D., Warm J. S., & Colligan M. J. (1985). Extended workdays: Effects on performance and ratings of fatigue and alertness. Behavior Research Methods, Instruments & Computers, 17, 1, 6-15.

This investigation provided a laboratory test of long workdays and served as an initial step in developing a field-test battery which is sensitive to fatigue. Six subjects worked both a 12-hr/4-day workweek and an 8-hr/6-day week at a data entry job simulation. Before and after the first and last days of each week, they completed a battery of brief measures testing cognitive, perceptual-motor, task-sharing, motor, and sensory capacities, as well as subjective feelings. Results suggest that the 12-hr/4-day week was more fatiguing than the 8-hr/6-day week. In the data-entry job, it was easier to improve performance across the 8-hr/6-day week. This result suggested that the fatigue of the 12-hr days slowed the rate of improvement across the week. With respect to the test battery, two cognitive tasks (grammatical reasoning and digit addition) and several self-report scales also reflected greater fatigue in the 12-hr/4-day week. Performance efficiency decreased and reports of drowsiness and lack of concentration increased from the beginning to the end of the final 12-hr workday. On the basis of these results, it was concluded that the test battery has utility for the assessment of the potential fatigue effects of long workdays in actual work settings.

330. Rotondo G. (1969). Experimental contribution to preventive and therapeutic treatment of flight fatigue. Revista Di Medicina Aeronautica E Spaziale, 32, 231-268. (In Italian.)

The author frames nosologically, flight fatigue syndrome through its definition, the study of its pathogenesis, diagnostic methods, symptomatology and traditional therapy. Results of experimental research are summarized. Investigations were carried out to test the possible effectiveness of a few cortical hormones, as dehydroiso-androsterone as well as of association of metabolitic drugs, as adenosine trephosphoric, and cocarbossilasis, and acetyl aspartic acids and citrulline in preventive and therapeutic treatment of this syndrome.

For each substance studied the author surveys possible physiopharmacologic mechanisms of its favorable action in therapy and prevention of operational fatigue. This survey is carried out mainly in light of the modern concepts on etiopathogenesis of this syndrome. The author states that the favorable results obtained with the tested drugs, mainly with dehydroisoandrosterone in manifest flight fatigue, and with acetyl aspartic acid-citrulline association in mild and initial syndrome, are such as to encourage further and larger clinical

experimentation. This proposed study would be useful in view of flight safety and flight accident prevention, as well as of prompt recovery of fatigued flight personnel, and of preserving conditions of perfect psychophysiological efficieny.

331. Rotondo G. (1978). Workload and operational fatigue in in helicopter pilots. Aviation, Space and Environmental Medicine, 49, 430-436. (In English). Revista Di Medicina Aeronautica E Spaziale, 1976, 39,91-116. (In Italian). (NATO/AGARD Report No. CP-217).

In light of the modern etiopathogenic views, a brief review was made concerning possible causes of operational fatigue to which flying personnel in general are exposed in the exercise of flying activity. The author describes the meaning and importance of the various stressing factors that constitute the physical and psychic workload to which the helicopter pilot is subjected in performing his professional activities. Also analyzed are the influences exercised, both separately and jointly, on the genesis of flight fatigue in helicopter pilots by stressing and fatiguing effects of vibrations, noise, and psycho-emotional and psycho-sensorial factors related to the variety and danger of utilization of this modern aircraft. Such an analytical investigation enables the author to conclude that one must admit that helicopter piloting involves a psychophysical workload certainly no less than that required by more powerful and faster aircraft.

332. Rubin R. T., Kollar E. J., Slatter G. G., & Clark B. R. (1968). Excretion of 17-hydroxycorticosteroids and vanillylmandelic acid during 205 hours of sleep deprivation in man. (NMNRU Report No. 68-17). San Diego, CA: US Navy Medical Neuropsychiatric Research Unit.

Previous studies of adrenocortical activity during sleep deprivation revealed unchanged or lowered plasma 17-hydrocorticosteroid (17-OHCS) levels and either unchanged, lowered, or elevated urine 17-OHCS values, depending on the subject and the length of the deprivation period. In this study, plasma 17-OCHS, urine 17-OHCS, and urine vanillymandelic acid (UMA) were measured during 205 hr. of wakefulness, the rational being that an extended period of sleep deprivation might result in more definitive physiological responses. Plasma 17-OHCS in all 4 subjects decreased to a low point at about 90 hr., then increased to peak values at about 170 hr. Urine 17-OHCS values tended to reflect changes in plasma 17-OHCS levels. Urine UMA excretion varied considerably among the 4 subjects. The results suggest that prolonged sleep deprivation per se results in only, if any, specific activation of the pituitary-adrenocortical axis and in variable increases of catecholamine biosynthesis. Differing patterns of physiological activity may

occur among sleep-deprived subjects.

333. Rutenfranz J. (1975). The physiological basis of industrial work. (NASA Report No. TT F- 16, 808). Translation of " Physiologische Grundlagen der Industriearbeit", Zentralblatt fuer Bakteriologie, Parasitenkunde und Infektionskrankheiten Abteilungl, Reihe B. Originale, Vol. 158, 1973, pp. 219-238). Washington, DC: National Aeronautics and Space Administration.

In a brief review three main topics of modern industrial work are discussed:

1) Relationship between physical fitness and the endurance limit at heavy work;

2) Problems of rest pauses and their physiological and psychological implications;

3) Basic problems of circadian rhythms in relation to night and shift work.

334. Rutenfranz J., Knauth P., & Colquhoun W. P. (1976). Hours of work and shiftwork. Ergonomics, 19(3), 331-340.

The time elements of a working day, the duration of working time and the time positioning of working time are described under ergonomics aspects. The reasons for shiftwork, different types of shiftwork as well as effects on health and on family and social life are discussed. The following physiological criteria for optimal shift-schedules are presented: (1) Single night shifts are better than consecutive night shifts. (2) At least 24 hours free time should be allowed after each night shift. (3) The cycle of a shift system should not be too long. (4) The length of the shift should be related to the type of work. (5) In connection with continuous shiftwork as many free weekends as possible should be arranged.

335. Ryman D. H., Naitoh P., & Englund C. E. (1984). Minicomputer administered tasks in the study of effects of sustained work on human performance. Behavior Research Methods, Instruments, & Computers, 16(2), 256-261, & (NHRC Report No. 83-21). San Diego, CA: US Naval Health Research Center.

Computer administration of tasks during laboratory studies of human performance changes in continuous work has made data collection and analysis easier and quicker. Six tasks and scoring programs were developed for the MINC 11 (Digital Equipment Corporation's Modular Instrumentation Computer) with an A/D converter and a clock module. Four of these tasks measured different types of reaction time; the TRAP task measured the response times of alternate pressing of two buttons, the Simple Reaction Time task recorded response times,

to a visual stimulus, the Alpha-Numeric Visual Vigilance task measured response latencies to correct and incorrect (disjunctive) visual signal detections, the Four Choice Serial Reaction Time task measured reaction time involving correctness of choice to a visual stimulus in one of four areas on a terminal screen.

Two other tasks presented via computer were the Logical Reasoning Task, measuring correctness of complex information processing, and a Mood-Symptom-Fatigue and physiological state survey. The task programs were written in assembly language (MACRO-11), and the scoring programs in Fortran IV. The programs have been run on a MINC-11/03 and 11/23 computers, with two double-density disk drives, two terminals and a printer.

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336. Saldivar J. T., Koffmann S. M., & Melton C. E. (1977). Sleep in air traffic controllers. (FAA Report No. AM-77-5). Oklahoma City, OK: Federal Aviation Administration, Civil Aeromedical Institute. (DTIC No. AD A038-297/8ST).

Data obtained from sleep logs maintained for a period of 5 weeks by 185 air traffic controllers indicate that on a weekly basis there is no significant difference in the amount of sleep obtained by controllers working the 2-2-1 rotation pattern and that obtained by those on the 5-day rotation pattern. Controllers working the 2-2-1 rotation pattern slept significantly less prior to the midshift than they did before the evening and day shifts. On both the 2-2-1 and 5-day rotation patterns, the most sleep obtained was on the evening shift followed by the day shift and midshift respectively. Approximately half the controllers indicated satisfaction with their present shift rotations; however, preferences indicate that they would prefer to work a shift rotation that excluded the midshift. Age and experience do not appear to be related to pattern of sleep or amount of sleep obtained. "Fatigue", "weakness", and "somnolence" were complaints most often expressed on the midshift on both rotation patterns.

337. Samn S. W., & Perelli L. P. (1982). Estimating aircrew fatigue: A technique with application to airlift operations. (USAF SAM Report No. TR-82-21). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A12-531/9).

This report proposes a method of assessing aircrew fatigue based on work/rest profiles. Possible circadian desynchronization and cumulative fatigue an aircrew may have experienced are considered. The method was used to assess aircrew fatigue during computer-simulated airlift operations. It shows quantitatively how flying-hour limitations can affect average aircrew fatigue and system performance.

338. Sanders, A.F. (1983). Some issues in research on effects of sustained work and sleep loss on performance. In: J. Ernsting (Ed.), Sustained intensive air operations: Physiological and performance aspects. Proceedings of the NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France, April 1983. (NATO AGARD CP-338) pp 13-1 - 13-7. Loughton, Essex, United Kingdom: Specialised Printing Services Ltd. (DTIC No. AD P002-988).

This paper argues that effects of sustained operations are minor as compared to those of sleep loss and diurnal rhythm, and that such effects are selectively related to the nature of performance demands. Examples of the author's own research and that of others on these topics are given.

339. Sanford J. F., Steinkerchner R. E., Cantrell G. K., Trimble R. W., & Hartman B. O. (1971). Alertness, fatigue, and Morale of Air Force Sentries. (USAF SAM Report No. TR 71-34). Brooks AFB, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD734-766).

A four-phase study investigating the degree of alertness and subjective fatigue among sentry police and evaluating general manning, management, and morale problems within Security Police squadrons was conducted. Subjects included sentries stationed within CONUS and in Southeast Asia (SEA). Results showed that CONUS sentries experienced increasing feelings of fatigue but no measurable loss of alertness during 8-hour tours, while SEA sentries showed both increasing fatigue and diminishing alertness. Differences were discussed with respect to morale and manning problems, and recommendations for improving morale were made.

340. Sawka M. N., Gonzalez R. R., & Pandolf K. B. (1982). Effects of sleep deprivation on thermoregulation during exercise. (USARIEM Report No. M-6-83). Natick, MA: US Army Research Institute of Environmental Medicine. (DTIC No. AD A124-982/0).

Five fit males completed a practice, control (C) and sleep deprivation (SD) exercise test. Two nights of normal sleep preceded the C test and 33 h of wakefulness preceded the SD test. These tests consisted of 20 min of rest followed by 40 min of cycle ergometer exercise (50% of peak VO_2) in a temperature (T sub a=28 C, rh=30%) environment. Esophageal temperature (T sub es), local sweating rate (ds) and chest skin conductance (K sub ch) were continuously measured. In comparison to control levels, sleep deprivation resulted in a 26% increase in Tes from rest to final exercise values. Total body sweat rate, calculated from Potter balance measurements, was 27% less for the SD test than the C test. Both d sub s and

K such ch values were lower during the final 20 min of exercise for the SD than C test.

An asynchronous rather than a normal synchronous ds pattern was frequently observed during the SD test. The ds threshold was not changed but the ds sensitivity was 38% lower during the SD than C test. During the SD test, the K sub ch threshold was 0.11 degrees C lower and K sub ch sensitivity (delta K such ch/delta Tes) was 42% lower than during the C test.

These data indicate that sleep deprivation decreases the potential for evaporative and dry heat loss during moderate intensity exercise. The reduced d sub s and K sub ch responses were mediated by the central nervous system.

341. Schiflett S. G., Cadena D. G., Hemion R. H. (1969). Headlight glare effects on driver fatigue. (SWRI Report No. AR-699). San Antonio, TX: Southwest Research Institute. Department of Automotive Research. (NTIS No. PB 190-154).

Two separate studies were conducted with real and simulated night operation to examine the phenomenon of fatigue in drivers by a variety of physiological and psycho-physiological sensors and indicators, including EEG, EMG, reaction and task performance measures, and changes in 17-OHCS level in body fluids. The objective of these studies was to differentiate the onset and development of fatigue in drivers with respect to specific modes of opposing vehicle head-lights. The experiments were essentially unsuccessful in finding a sensory technique of adequate sensitivity to provide such discrimination, although gross changes related to fatigue were observed.

342. Schmidt-Amelung J. (1974). Effects of two transatlantic-flights in rapid sequence upon the 24-hour rhythm in the urinary excretion of 17-hydroxycorticosteroids and catecholamines. (DLR-FB Report No. 74-36). Translation of: "Auswirkung en von zwei Transatlantikflugen in rascher Folge auf die Tagesrhythmik in der Ausscheidung von 17-Hydroxycorticosteroiden und Catecholaminen." Bonn-Bad Godesberg, Germany: Deutsche Forschungs-und Versuchsanstalt fur Luff-und Raumfahrt.

The effects of two transatlantic flights in rapid sequence upon the 24-hour rhythm in the urinary excretion of 17-hydrocycortico-steroids (17-OHCS) and catecholamines were studied in 8 male subjects. Flights were performed as outgoing and return flights between Frankfurt and Chicago with a time shift of 6 hours and a stopover time of 26 hours. The results showed distinct excretion patterns in all studied functions on

day 1 and 2. The diurnal rhythm of the 17-OHCS showed marked time shift effects on day 1 after return. The changes and their operational significance for the flying personnel are discussed.

343. Shingledecker C. A. (1983). Behavioral and subjective workload metrics for operational environments. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advirosry Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France April 1983. (NATO/AGARD Report No. CP-338, pp. 6-1 to 6-10). Loughton, Essex, England: Specialised Printing Services, Ltd. (DTIC No. AD P002-983).

The assessment of crew performance capability under conditions of sustained air operations requires the use of specialized measures of operator workload which are matched to the nature of the investigation and to the environment in which the workload evaluation must be conducted. In many cases, the effects of severe combined stressors and of aircrew performance requirements on mental workload cannot be studied in the laboratory, and must be addressed in high fidelity simulation or during operational test exercises.

This paper examines the advantages and limitations of traditional subjective report and behavioral measures of workload for application in operational environments. In addition, recent efforts at the US Air Force Aerospace Medical Research Laboratory to develop improved field-usable subjective and behavioral secondary task metrics are described.

344. Siegel A. I., Pfeiffer M. G., Kopstein F. F., Wilson L. G., & Ozkaptan. (1979). Human performance in continuous operations: Volume I. Human performance guidelines. (ARI Report No. Research Product 80-4a). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

This document provides guidelines to the military commander on expected human performance degradation of continuous ground combat. Degradation projections are based on extrapolations from scientific literature and realistinc scenarios of continuous operations.

The advantages and application of task restructuring, task reallocation, and work rest managment concepts in the continuous operations context are presented along with considerations for training, system design and performance support.

Comprehensive tables show anticipated performance degradation for specific duty positions in the mechanized

infantry, artillery, armor and fire support (FIST) categories. Methods are discussed for minimizing the anticipated degradation.

345. Siegel A. I., Kopstein F. F., Federman P. J., Ozkaptan H., Slifer W. E., Hegge F. W., & Marlowe D. H. (1981). Management of stress in army operations. (USARI Report No. 81-19). U.S. Army Research Institute for the Behavioral and Social Sciences, and Walter Reed Army Institute of Research.

The two most important ingredients of combat stress are physical fatigue and mental stress. Combat stress is a result of exposure to battle conditions, just as injury and physical disease are results of battle conditions. In past wars, it was revealed that there was one combat stress casualty for every four wounded in action--one for every three wounded during lengthy periods of intense combat.

In a war characterized by continuous operations a high intensity integrated battlefield, the relationship of stress casualties to wounded in action is expected to be at least one to three and conceivably even greater. However, combat stress is not solely a medical problem. It is also a command problem-both in terms of numbers lost from duty and reduced performance of duty.

Battle in Central Europe against forces of the Warsaw Pact is the most demanding mission the US Army could be assigned. If such conflict were to occur, it would most likely take the form of continuous ground combat operations. By their nature, continuous operations provoke severe combat stress. Reinforcements and logistics will be difficult to maintain and force maintenance will be a prime issue. The effects of major sources of stress on fighting capability are reviewed against this background.

This report integrates and presents the latest research information with respect to the recognition, control, and management of stress in combat. It is designed principally for use by military personnel at Company level and below.

346. Siegel P. V., Gerathewohl S. J., Mohler S. R. (1969). Time-zone effects on the long distance air traveler. (FAA Report No. AM-69-17). Washington, DC: Federal Aviation Administration, Office of Aviation Medicine. (DTIC No. AD 702-443).

Findings are presented on the consequences of rapidly crossing numerous time zones, such as occurs in present-day jet aircraft travel. Conclusions reached by FAA researchers and scientists of other laboratories are included, together with

recommendations for overcoming time-zone fatigue. These recommendations are for use by the individual long distance traveler. A practical formula is given which describes how one may compute the rest period following a long distance trip. This period is to enable the biological rhythms to rephase in order that the traveler will be in proper physical and mental condition to pursue his responsibilities.

347. Siegel A. I., Taylor S. E., Shuler L., & Pfeiffer M. G. (1979). Human performance in continuous operations guidelines. (USARI Report No. RP 79-8). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

This handbook provides guidelines to the military user on expected human performance capability during continuous combat. The performance of squad-level soldiers engaged in continuous operations is subject to constraints and degradation in many critical tasks. This Guidebook presents, in handbook form, a detailed analysis of 76 selected critical tasks performed by a mechanized infantry squad and the platoon leader. The analyses give the areas of projected performance decrement and the reasons for the projections, and implications for doctrine, strategy, training, and equipment. The information will be useful to military tactical planners, training specialists, and design engineers.

348. Siegel A. I., Wolf J. J., Schorn A. M., & Ozkaptan H. (1981). Human performance in continuous operations: Description of a simulation model and user's manual for evaluation of performance degradation. (USARI Report No. TR-505). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

User instructions and reference materials are presented for a computer simulation model which analyzes performance effectiveness when variables such as continuous time in battle, light level, sleep permitted are varied alone or in combination. The model is designed for interactive operation at a terminal by a user with minimum sophistication in computer use. The primary output of the model is tables of personnel effectiveness degradation by day, type of combat unit, and each of five "combat factors." Along with interpretive guidance, step-by-step procedures are presented for the preparation of model data and for running the model.

349. Simonson E. (Ed.). (1971). Physiology of work capacity and Fatigue. Springfield, IL: Charles C. Thomas.

This volume is a comprehensive review of the physiological aspects of fatigue. The author concentrated on fundamental problems and mechanisms of fatigue with representative

references for various problems discussed. These problems include cradiovascular, respiratory, metabolic, biochemical, and physiochemical functions and their relationship to fatigue. The information given provides the basis for practical applications in athletics, military situations, occupational work, extreme environment (temperature and high altitude), and medicine. However, the applications are not spelled out in detail. No systematic differentiation between fatigue and exhaustion is made.

350. Simonson E., & Weiser P. L. (Eds.). (1976). Psychological aspects and physiological correlates of work and fatigue. Springfield, IL: Charles C. Thomas.

This volume is meant to be mutually supplemental to Simonson's Physiology of Work Capacity and Fatigue. Due to the fact that the separation of physiological and psychological aspects of fatigue is somewhat arbitrary the first part of the volume contains chapters with primarily a physiological orientation followed by chapters with primarily a psychological orientation. The book cointains six sections which cover physiological background, motor, sensory, and central processing aspects of fatigue, aging and introspective aspects of work and fatigue.

351. Soldier Support Center. (1983). Soldier performance in continuous operations. (U.S. Army Field Manual No. FM 22-9). Washington, DC: Headquarters Department of the US Army.

This manual deals with methods for sustaining soldier performance during continuous operations. Conflict in Central Europe against forces of the Warsaw Pact has been called the most demanding mission that the US Army could be assigned, but a continuous mission may be required anywhere in the world. In any such conflict, combat operations are expected to continue around the clock at a high pace. Soldiers will be required to fight without letup for extended periods. Under these conditions, the soldiers' performance will suffer. The procedures for ensuring soldier performance capability and for conserving it in battle need to be well understood.

This manual:

1) presents principles for countering and slowing the erosion of soldier resources.

2) shows methods of conditioning units for continuous operations and for preserving their fighting capabilities during continuous combat.

3) presents factors governing rates and degrees of progressive performance degradation in detail.

4) illustrates differences in expected effectiveness for various types of combat activity over 120 continuous mission hours.

The information can be used by leaders who plan and manage soldier performance in extended, continuous combat missions. In missions of this type, soldier resources can dwindle rapidly. This problem must be addressed early during initial planning stages. This manual contains guidance for reducing the impact of adverse effects on soldier performance and for prolonging soldiers' fighting effectiveness.

352. Sonderfeld A. T. (1977). The influance of the journey's time of day on the de- and resynchronization of the 24-hours rhythm body temperature after transatlantic flights. (DLR Report No. 77-10). Bonn-Bad Godesberg, Germany: Institut fur flugmedizin, Deutsche Forschungs-und Versuchsanstalt fur Luft- und Raumfahrt, Forschungsbericht.

The influence of a time-shift of six hours on the 24-hour rhythm of body temperature was investigated in a group of 8 students in Germany and the U.S.A. by measuring their rectal-temperature after transatlantic flights. The temperatures were taken continuously over the first 6 days and on days 8 and 13 after an East-West flight and after a West-East flight. In contrast to previous studies in which the West flight was day-flight, the East-flight a night flight, both flights in this case were day-flights. The time of resynchronization after the East-West flight ran up to seven days, the time after a flight in the opposite direction up to ten days. This result squares with the results gained from previous experiments on day and night flights in so far as an influence of the hour of the day, at which the flight is carried out, is not supposed.

353. Spinweber C. L., & Johnson L. C. (1983). Psychopharmacological techniques for optimizing human performance. (USNHRC Report No. 83-11). San Diego, CA: US Naval Health Research Center.

In operational environments, administration of psychopharmacological agents could be employed to optimize and maintain human performance. One technique of considerable military importance is use of sleeping aids to promote rapid sleep onset and permit efficient utilization of rest periods. A methodology for evaluation of sleeping aids for military use is described. In a laboratory study of the triazolobenzodiazepine triazolam 0.5 mg, sleep latency was reduced and morning performance was unimpaired, although a clear performance decrement was present up to 5 hours post-administration. Triazolam also produced anterograde amnesia and elevated auditory threshold for arousal from sleep. In operational use, triazolam could be effectively administered when rest periods of 8 hours duration are scheduled.

The dietary amino acid 1-tryptophan (4g) was effective in

reducing daytime sleep latency in normal sleepers, suggesting its usefulness in alleviating sleep disturbances associted with jet lag and altered work-rest schedules. In night-time administration to chronic poor sleepers, l-tryptophan of 3g reduced sleep latency after three nights of administration and had no adverse performance effects.

The suitability of both triazolam and l-tryptophan for military use will be further evaluated in field research and tested in operational environments. Another psychopharmacological approach is administration of carefully-chosen stimulants to maintain alertness and performance effectiveness when there is no opportunity for sleep. The techniques developed in this on-going research program in behavioral psychopharmacology will be employed to evaluate stimulants for operational use.

354. Stamper D. A. (1978). Physiological, psychological, and symptomatic factors affecting prolonged physical performance. (LAIR Report No. 56). Presidio, San Francisco, CA: Letterman Army Institute of Research. (DTIC No. AD A059-965/4ST).

During long-term physical performance tasks, individuals rely on feedback mechanisms which enable them to adjust the work load level. This feedback process is hypothesized: (1) to be important when successful completion of the task and/or time limitations are imposed on the individual; (2) to reflect ongoing physiological changes; and (3) to be affected by an individual's personality which can modify the perception of sensory information. Only one subscale from three personality tests, i.e., the Disinhibition subscale of the Sensation Seeking Scale (SSS-DIS), was related to total ride time. However, contrary to the inhibition/satiation model proposed, the relationship was negative. Specifically, individuals that performed best on this physical endurance task were those who tended to show the lowest scores (the more inhibited persons). This suggests that the original model that has as its basis the inhibition/satiation hypothesis may not be sufficient. Perhaps specific psychosocial, work intensity, and stimulus intensity factors must also be considered.

355. Stave A. M. (1977). The effects of cockpit environment on long-term pilot performance. Human Factors, 19, 503-514.

A fixed-base helicopter simulator was used to examine pilot performance as influenced by noise, vibration, and fatigue. Subjects flew the simulator for periods ranging between three and eight hours while exposed to vibrations (at 17 Hz) ranging from 0.1 to 0.3 g, and noise stimuli varying between 74 (ambient) and 100 dB. Despite reports of extreme fatigue on these long flights, subject performance did not

degrade. Within the limits of this study, performance tended to improve as environmental stress increased. However, subjects did suffer from lapses resulting in abnormally poor performance. These lapses are probably of short duration (seconds) and occur at unpredictable times. If such lapses occur in actual flight, they could provide an explanation for many so-called "pilot error" accidents.

356. Stokes J. W., Banderet L. E., Francesconi R. P., Cymerman A., & Sampson J. B. (1975). The field artillery fire direction center as a laboratory and field stress-performance model: I. Position paper; II. Progress towards an experimental model. In: H. S. Fuchs, G. Perdriel, & A. Gubernale (Eds.), The role of the clinical laboratory in Aerospace Medicine. (AGARD Conference Proceedings No. 180, pp. A1-A10). NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Ankara, Turkey. London: Technical Editing & Reproduction Ltd.

The 5-man fire direction center (FDC), common to all Field Artillery batteries, was chosen for study in the laboratory and field to evaluate the impact of environmental and situational stress on the complex performance of highly trained and motivated individuals working together as a team. The working environment of a field FDC was simulated within a hypobaric chamber and a volunteer FDC team from an elite U.S. Army unit was tested using realistic matched "combat" scenarios. To minimize practice effects, the team was initially given 26 h of "intensified training" (ITS). The team was then tested single-blinded as to the altitude condition for 48 hours at both 427 m (control) and 4242 m; the team rested 22 h between ITS and control and 48 h between control and the high altitude conditions.

Mission performance during ITS and control was sensitive to disrupted sleep-rest cycles, with errors clustering at times of low arousal. At high altitude, performance was less efficient during the first 10 h; most serious errors involved processing of digits. Overlearned FDC skills showed little deterioration even when the men were ill with acute mountain sickness; compensatory behaviors were evident and technical performance for the last 38 h at altitude equalled or exceeded control. Thus, in this study communications, psychomotor, and judgment aspects of FDC performance, as well as measures of symptoms, mood, and neuroendocrine response, appear differentially sensitive to psychological stress, hypoxia, and fatigue. The rationale and objectives of this program are given as well as initial experimental results.

357. Stolgitis W. C. (1969). The effects of sleep loss and demanding work/rest cycles: An analysis of the traditional Navy watch system and a proposed alternative. Monterey, CA: US Naval Postgraduate School. (DTIC No. AD 706-027).

An analysis of the traditional Navy watch system and a proposed alternative are presented. Current research on sleep deprivation and the effects of demanding work/rest schedules is documented and discussed as a basis for key assumptions in the analysis. Methodology is also presented for determining the relative ability of the two schedules to meet the assumed minimum sleep requirements. The results favor the alterrate schedule as the more efficient for allocating available time resources to meet established sleep requirements.

358. Stolze H. J. (1971). Circadian rhythms of pilots' performance in a flight simulator. (DLR Report No. FB-71-14). Bonn, West Germany: Deutsche Forschungs und Versuchsanstalt Fuerluft and Raumfahrt. (DTIC No. AD 855-740).

In order to investigate variations in pilots' performance, possibly existing in dependency on daytime, 18 pilots had to perform standarized instrument flight in a simulator. Their deviations from the preset flight task were measured and their responses to flight incidents were evaluated. The results showed almost constantly high performance plateau during the late afternoon and a trough during the night hours between 3 and 6 a.m. The range of oscillation in performance parameters, amounting to 28.1% of the 24-hour mean was considerably larger than that of the reaction time with 8.1%.

From the results it can be concluded that, considering the nightly trough in performance, pilots on night flight duty may be subjected to substantial stress. A possible safety risk can be reduced by a sufficiently long rest period prior to the night flight duty and by limiting the duration of the night shift.

359. Stone L. W., & Duncan C. E. (1984). Effects of extended use of AN/PVS-5 night vision goggles on helicopter pilots' performance. (USAARL Report No. 84-3), Fort Rucker, AL: US Army Aeromedical Research Laboratory.

The effects of extended use of AN/PVS-5 night vision goggles (NVG) were investigated by observing 10 NVG helicopter instructor pilots during two 6-hour missions. Each mission consisted of three 2-hour flights during which pilot control inputs and aircraft status variables were recorded in flight. Questionnaires were completed before the first mission and after the NVG mission.

Only the out-of-ground-effect hover showed a statistically significant carryover effect; that is, subjects who flew without goggles before flying with NVG demonstrated a greater difference in hover flight performance variability than those who flew naked eye after NVG flight. In the traffic pattern (final approach segment), there was a significant difference between the visual conditions only. The postflight questionnaire responses revealed a concern over what was described as a "lack of concentration" and a "decline of mental alertness." Some physiological stress reactions were reported. None of the three maneuvers analyzed revealed a significant effect on performance across flights.

360. Stone L. W., Krueger G. P., & Holt W. R. (1982). Pursuit rotor tracking performance in conjunction with extended flight operations in a helicopter simulator. (USAARL Report No. 82-6). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

Six US Army Initial Entry Rotary Wing School graduates participated as subjects and flew a simulator for 14 hrs per day in a week-long study to examine the effects of extended simulated helicopter operations on pilot performance. This report covers pursuit tracking skills. Using a photoelectric rotary pursuit device, three fixed patterns (a square, a circle, and a triangle) were presented to each subject three times daily for 5 days. An analysis of the results revealed a significant difference in subject performance between patterns. It also revealed a statistically significant difference in performance over days on one of the patterns--the triangle. The thread woven through these results was one of relative complexity. It suggested the effects of sustained operations interfered with the aviator's ability to fully integrate his mental and psychomotor skills in order to meet the requirements of a more complex task.

361. Storm W. F. (1980). E-4B Crew fatigue associated with 30-hour IOT&E mission. (USAF SAM Report No. TR-80-40). Brooks Air Force Base, TX: School of Aerospace Medicine. (DTIC No. AD A094-839/8).

The Air Force Test and Evaluation Center (AFTEC) conducted an independent 45-day IOT&E of the Advanced Airborne Command Post (E-4B aircraft) system from 27 December 1978 to 11 February 1979. A 30-hour continuously airborne mission was flown to demonstrate the extended mission capability of the E-4B system. A battery of psychobiological measures was used to evaluate crew fatigue associated with the extended mission. The battery consisted of sleep surveys, subjective fatigue ratings, and mood surveys, as well as endocrine/metabolic indices derived from urine samples.

Data were systematically collected from 66 crewmen at 4-hour intervals during the mission and for 3 1/2 days after the mission. The data were reduced for six functional crew groups: flightcrew, stewards, radio operators, radio maintenance technicians, aircraft maintenance technicians, and the National Emergency Airborne Command Post (NEACP) battle staff.

Fatigue and stress levels that occurred during the 30-hour mission were moderate and not suggestive of compromises in performance and safety. Fragmented sleep acquired in the bunks and passenger seats was of restorative value and contributed to the abeyance of severe fatigue and negative mood states during the mission. Severe levels of subjective fatigue were reported a few hours after mission completion, but after 2 nights of uninterrupted sleep in the home environment, the crews were sufficiently recovered to resume normal ground and flight duties.

362. Storm W. F. (1980). Mission crew fatigue during Rivet Joint Block II demonstration/evaluation. (USAF SAM Report No. TR-8037). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A094-822/4).

RIVET JOINT is a USAF Electronic Systems Command (ESC) airborne (RC-135) reconnaissance system. The objectives of an ongoing modernization program are to improve mission capability and manpower utilization through use of state-of-the-art computer technology and surveillance equipment. A prototype modernized system recently underwent testing and evaluation in the operational environment. ESC/SD requested the the USAF School of Aerospace Medicine evaluate the impact of the system on operator stress and fatigue.

Psychobiological data were systematically collected from 13 operators over 6 consecutive days, including two 8-hour airborne test missions. The subjective fatigue and physiological cost associated with the test missions were moderate and did not suggest compromises in performance and safety. The operators were fully recovered from each of the test missions after an extended postmission night of sleep.

363. Storm W. F. (1983). Aircrew fatigue during extended transport, tactical, and command post operations. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France April 1983. (NATO/AGARD Report No. CP-338, pp. 21-1 to 21-16). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-991).

Self-ratings of subjective fatigue and sleep logs provide a simple and useful means of evaluating aircrew fatigue during real-world operations involving large numbers of participants working irregular schedules. Evaluations of extended USAF operations involving transport, tactical, and airborne command post systems are reviewed. Following onboard crew rest on C-141 transport aircraft flying 8- to 9-hour missions, aircrew performance in simulator missions was significantly deteriorated and accompanied by reports of severe fatigue.

Tactical aircrews are being trained and evaluated in unit flying at the fast pace expected in the first crucial days of an armed conflict. Flying 2 to 3 sorties a day for a week or more resulted in reports of only moderate fatigue. Daily fatigue was ameliorated by a night of quality sleep. During a 30-hour airborne command post mission, crew fatigue was moderate and not suggestive of compromises in performance. After mission completion, severe levels of fatigue were reported.

364. Storm W. F., Dowd P. J., Noga G. W., Schuknecht L. A. (1981). Fatigue in double-crew aerial-refueled transport missions. (USAF SAM Report No. TR-81-23). Brooks Air Force Base, TX: School of Aerospace Medicine. (DTIC No. AD A104-754/7).

Military Airlift Command (MAC) contingency plans call for extending strategic airlift capability by flying C-5A aircraft with double crew and aerial refueling. This mode of operation is known as the Blue and Gold concept. Standard MAC operations limit the C-5A basic crew-duty day to 16 hours, after which a minumum en route crew-rest/ground time of 16.25 hours is required before flying duty can be resumed. Under the Blue and Gold concept, two crews, one designated Blue and the other Gold, alternate being on duty on the flight deck and off duty in crew rest. The mission progresses as the two crews alternate responsibility for the aircraft. Thus, under the Blue/Gold concept, all en route crew rest and sleep occur onboard the aircraft, and much of this time is while the aircraft is airborne.

Self-ratings of subjective fatigue and sleep histories were used to evaluate crew fatigue during five Blue/Gold missions, two each of 32 and 56 hours and one of 44 hours. Results are presented and discussed.

365. Storm W. F., & Gray S. F. (1978). Minuteman missile crew fatigue and 24-hour alerts. (USAF SAM Report No. TR-78-19). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A56-561/4ST).

A battery of psychobiological measures was used to evaluate the degree of fatigue experienced by missile crews performing 24-hour continuous duty alert tours at Minuteman launch control centers. Operationally significant findings relative to the duty schedule occurred for subjective fatigue scores, hours slept per day, and urinary outputs of 17-OHCS, sodium, and potassium. The moderate postalert fatigue and physiologic cost present at the end of the 24-hour alerts were ameliorated by one night of undisturbed sleep. Values indicative of severe crew fatigue or stress were never attained for any of the measures. A buildup of cumulative fatigue ove several alerts could be avoided by scheduling a minimum of tw consecutive nights sleep at home between alerts. The impact of the duty schedule on contingency and emergency situations was also considered.

366. Storm W. F., & Hapenney J. D. (1976). Mission-Crew fatigue during Rivet joint operations. (USAF SAM Report No. TR-76-36). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine. (DTIC No. AD A032-437/6ST).

Subjective fatigue and sleep data were collected for a USAF Security Service airborne mission team before and during an airborne mission. The primary purpose of the test was to refine the procedures and analytical techniques in preparation for an upcoming demonstration/evaluation of a new and modernized system. Results indicated that only minor changes in procedures and techniques were necessary. The data also provide unique baseline information for future comparison and evaluation of similar data from the modernized system.

367. Storm W. F., & Merrifield J. T. (1980). Fatigue and workload in four-man C-5A cockpit crews (Volant Galaxy). (USAF SAM Report No. TR-80-23). Brooks Air Force Base, TX: School of Aerospace Medicine. (DTIC No. AD A094-498/3).

Triple Inertial Navigation Systems (INS) are being installed on C-5A aircraft. At the request of the USAF Airlift Center, aircrew fatigue and workload were evaluated in 4-man C-5A cockpit crews (aircraft commander, copilot, and 2 flight engineers) performing typical long-range transport missions on

triple-INS-equipped aircraft. Most of the navigator's duties were assumed by the pilots with the balance assigned to the flight engineer station. Considering subjective fatigue and workload findings, discussions with crewmen, the workloads reported during emergencies and aerial refuelings, and the operational requirements of wartime conditions, it was recommended that the 4-man C-5A crew concept not be implemented at this time.

368. Sussman D. E., & Morris D. F. (1970). An investigation of factors affecting driver alertness. (CAL Report No. VJ-2849-B-1). Buffalo, NY: Cornell University, Cornell Aeronautical Labs.

The study consisted of a review of the literature concerned with driver alertness, and an experimental investigation of the effects of three variables: driving time, acoustic noise, and task complexity on driver performance. The findings were that during long-duration, low-event driving, drivers showed a linear increase in road position error; during emergencies such as a blowout, the driver's position error increased after four hours of driving, and this increase is most marked under high noise conditions. In addition, the study revealed no degradation in performance attributable to the use of a "speed controller" (a device which automatically maintains a present speed). The study also includes suggestions for future research and possible methods of alleviating the effects of reduced alertness.

T

369. Tasker D. I., Kinel D. G., & Tredici T. J. (1975). Use of the ERG and EOG in evaluating the effect of sleep deprivation on visual function in flying personnel. Aviation, Space, and Environmental Medicine, 46, 943-945 and (USAF SAM Report NO. TR-75-248). Brooks Air Force Base, TX: US Air Force School of Aerospace Medicine.

The electroretinogram (ERG) and electrooculogram (EOG) are electrophysiological tests employed in ophthalmology to diagnose degeneration of injury to the outer half of the retina, including the rods and cones of the visual system. This pilot study was undertaken to determine if sleep deprivation of more than 24 hours in rated flying personnel may show an abnormality in retinal function as measured by the ERG and/or EOG. This may give insight to the visual function in flying personnel on deployment or other long missions where uninterrupted sleep may be a problem. The results of this study showed that some subjects deprived of sleep exhibited a statistically significant variance in their EOG ratios as compared to a nondeprived control group. No significant changes in ERG were detected. Principles and theory of eletrophysiological testing in ophthalmology are presented.

370. Taub J. M., & Berger R. J. (1973). Performance and mood following variations in the length and timing of sleep. Psychophysiology, 10(6), 559-570.

The relative effects of extended sleep, sleep deprivation, and shifts of accustomed sleep time on subsequent performance and mood were studied. Ten regular 2400-0800 sleepers worked on Experimenter-paced addition and vigilance tasks, and completed an adjective check list to rate their mood following 2100-0800 extended, 2100-0500 advanced-shift, 2400-0800 habitual, 0300-0800 deprivation, and 0300-1100 delayed-shift conditions of sleep. Accuracy and speed of response on the vigilance task were significantly poorer, and negative affect was significantly greater after the conditions of shifted sleep and altered sleep duration than after the habitual sleep condition. Changes in the mood and performance measures were unrelated to prior sleep length or any specific alterations in the electrophysiological patterns of sleep.

371. Tharp V. K. (1978). Sleep loss and stages of information processing. Waking and Sleeping, 2, 29-33, and (NHRC Report No. 77-43). San Diego, CA: US Naval Health Research Center.

The reaction time (RT) performance of seventeen male subjects was tested during four consecutive sessions: Baseline 1, Baseline 2, Sleep Deprivation (one night), and Recovery. The difficulty of the task was varied by manipulating two levels of stimulus discriminability, two levels of stimulus-response compatibility, and two levels of stimulus-response uncertainty in a balanced design. For each possible condition, the means of the 25% fastest and the 25% slowest RTs were calculated. These data were then analyzed and interpreted within the frame-work of an information processing model by means of the Sternberg (1969) additive factor method.

The results indicate that sleep loss has two primary effects on choice RT. First, it produces lapses in performance which are not readily interpretable within the framework of the proposed information processing model. Second, it produces a highly significant performance deficit in the fastest RTs, which appears to be a slowing of the response selection process.

372. Thompson, H. L. (1983). Sleep loss and its effect in combat. Military Review, 63, 14-23.

Chances are that future high-intensity battlefields will require soldiers to participate in almost continuous operations for long periods of time. Extended periods of work without rest and sleep eventually degrade the ability to function at an acceptable level. Procedures must be developed to permit soldiers, as well as leaders, to obtain at regular intervals the minimum amount of sleep needed to assure continued useful work.

The author discusses sustained combat operations, sleep, day-night cycles, jet lag, sleep deprivation and proposed countermeasures.

373. Thorne D., Genser S., Sing H., & Hegge F. (1983). Plumbing human performance limits during 72 hours of high task load. In S. E. Forshaw (Ed.), Proceedings of the 24th Defense Research Group Seminar on The Human as a Limiting Element in Military Systems: Volume 1. (NATO-DRG Report No. DS-A-DR(83) 170, pp. 17-40). Toronto, Canada: NATO Defence Research Group.

Eight volunteers, 18 to 21 years old, remained awake for 72 consecutive hours while working from 50% to 100% of each hour on a varied series of cognitive tasks. Although there were differences in individual performance patterns, all

subjects showed a moderate progressive reduction in accuracy and a large progressive increase reaction times across all tasks. The speed-accuracy product (throughput) showed greater sensitivity and less variability than speed or accuracy alone.

For each of eight tasks within a performance assessment battery, 72 hours of sleep deprivation produced an average decrement in throughput of about 74% relative to baseline performance. The magnitude and pattern of this decline was similar for tasks involving visual detection, mental arithmetic, logical reasoning, short term memory, attention and pattern recognition. Such uniformity is not forced, and may represent a general psychophysiological effect of sleep deprivation. The effect does not correspond to a change in the operating point on an underlying speed-accuracy tradeoff function, but to a change in the slope or shape of the function itself.

Relative throughput values averaged across all tasks revealed a circadian variation of approximately +10% of the baseline value, superimposed upon a monotonic decreasing function whose overall slope corresponds to a drop in throughput of roughly 24% per day. The circadian variation in performance was mirrored by a similar variation in oral temperatures, with temperature consistently leading performance by two to four hours.

Changes in subject's self-assessment of their subjective states tended to parallel changes in their performance, including the presence of an overlying circadian modulation.

All subjects experienced perceptual distortions and visual hallucinations, exhibited reduced appetite, and reported feeling cold.

A four hour nap at the end of the 72 hour period produced significant improvements in both subjective state and objective performance, although the absolute magnitude varied widely with the task and measure, being best for accuracy and less for speed or throughput. Post-nap throughput still averaged 23% below baseline.

374. Townsend R. E., & Johnson L. C. (1978). Relation of frequency-analyzed EEG to monitoring behavior. Electroencephalography and Clinical Neurophysiology, 47, 272-279.

Two experiments examined the relation of prestimulus electo-encephalographic (EEG) activity to choice reaction time (RT). In well-rested subjects (Experiment 1), trial-by-trial analysis indicated large variations in prestimulus EEG activity

which were unrelated to RT and large variations in RT which were unrelated to prestimulus EEG. In Experiment 2, subjects were deprived of sleep for one night and within-subject comparisons made between RT and EEG activity immediately preceding the 10 fastest and 10 slowest RT trials, and 10 trials where the subject failed to respond. Significant univariate correlations were found, largely between RT and the 15-20 c/sec range of EEG activity. A multiple regression analysis using 2-5 EEG frequencies indicated significant correlations of prestimulus EEG activity with RT, but with considerable subject-to-subject variability in the EEG frequencies contributing to the multiple R. The overall results suggest that there can be considerable variation in EEG activity which is unrelated to performance, except when the EEG fluctuations are secondary to changes in arousal which, in turn, affect performance.

375. Trumbull R. (1966). Diurnal cycles and work-rest scheduling in unusual enviornments. Human Factors, 8, 385-398.

The extension of man's working environment and its control have led to a new consideration of his "normal" neurophysiological and psychological rhythms. There are some fifty such patterns of fluctuating functions within man which have various degrees of influence upon his level of performance and ability to maintain performance. Data are provided from physiological and psychological research in an attempt to provide perspective for selection of appropriate personnel and establishment of work/rest or duty cycles in deference to these influences. Discussion includes application to aircrew schedules.

U

376. Ursin, H. Grahnstedt, S., Hansen, T., Myhre, K., Opstad, P.K., Walther, B. & Andersen, H. Attention, performance and sustained activation in military air traffic controllers. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France April 1983. (NATO/AGARD Report No. CP-338, pp. 22-1 to 22-10). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-992).

Trained military air traffic controllers report increased anxiety following, and demonstrate increased heart rate and urinary levels of epinephrine during a session of ground control interception. This type of activation has no detrimental effects on health, and is probably necessary for efficient performance even in well trained and coping personnel. There was also some rise in plasma levels of cortisol, but no other endocrine signs of any general activation.

However, if the coping potential of the men is threatened, in a real life situation, the activation picture is expected to be totally different, with a general activation which is far more taxing both on the information treating capacity and on the brain biochemistry. Psychological defense mechanisms will then be activated, which also impede performance. These psychological and physiological mechanisms are difficult to mimic, and occur only when the individual feels a real danger and threat to his or her coping potential.

The problem addressed in this paper is how personnel may be expected to perform during critical situations where they are asked to perform their best for long periods of time. What performance decrements may be expected to occur when high levels of attention and performance are demanded beyond ordinary working hours, and under conditions of high emotional load? To what extent can we predict who will perform best at any given time based on peace time training.

377. US Army Aeromedical Center. (1976). Stress and fatigue in flying operations. In: Army flight surgeon's manual. (Special Text STI-105-8, C-15). Fort Rucker, AL: US Army Aeromedical Center.

This chapter discusses stress definitions and measurements, stress concepts and etiologies, factors influencing or determining reactions to stress, fatigue diagnosis and classification, the prevention of fatigue, and the treatment and disposition of fatigue cases. Stress is identified as the major cause of fatigue and stresses present in the aviation environment are examined in detail. They include extreme environments, poor weather, hypoxia, human factors inadequacies in equipment design, and insufficient rest. Factors which determine reactions to stress, such as temperment, morale, discipline, and leadership are also examined. Fatigue is described in two major classifications: acute skill fatigue, which can be cured by a good night's sleep, and chronic fatigue, which requires more extensive treatment. Fatigue management can be accomplished by: maintaining physical fitness, minimizing self-imposed stress, obtaining adequate rest, and having pre-scheduled rest and recreation periods.

V

378. Vogel J. A., Sampson J. B., Wright J. E., Knapik J. J., Patton J. F., & Daniels W. L. (1979). Effect of transatlantic troop deployment on physical work capacity and work performance. (USARIEM Report No. T 3/79). Natick, MA: US Army Research Institute of Environmental Medicine.

Eighty-one soldiers of the 7th Brigade, 1st Cavalry Division, Ft. Hood, TX were studied for possible effects due to transatlantic deployment to Germany. The objective was to determine whether stresses of translocation across six time zones affected physical work performance and to separate out, in so far as possible, the causal factors of physiological work capacity and motivation or willingness to work. The anticipated symptoms of lassitude occurred in a majority of soldiers and persisted in some throughout the five days of evaluation in Germany. Aerobic work capacity was unaffected. Anaerobic capacity (muscular endurance) was decremented in the arms and possibly the leg muscles. Maximal isometric muscle strength was unaffected but dynamic strength was significantly reduced in arm muscles. Despite these alterations in symptoms, strength, and muscular endurance, work task performance was unaltered by translocation. It was concluded that neither motivation nor physiological work capacity were impaired sufficiently so as to affect overall work ability during the first five days after deployment to Germany.

W

379. Webb W.B. (1981). Sleep deprivation and physical fitness in young and older subjects. Journal of Sports Medicine, 21, 198-202.

A physical fitness battery was administered to six young subjects (18-22 years) and 10 older subjects (40-50 years) prior to and following two nights of sleep deprivation. The intent was to look at performance of personnel of ages near those normally found in military command and control positions for applications in sustained operations settings. Although the use of older subjects extended the range of phyusical fitness measures, sleep loss resulted in limited decremental effects on the measures.

380. Webb, W.B. (1982). Sleep and Biological Rhythms. In: Webb, W.B. (Ed.). Biological Rhythms, Sleep, and Performance, (pp. 87-110). New York: John Wiley & Sons.

The early history of the measurement of variations in physiological functions and the measurement of sleep reveals an extensive and sustained interest in, and interaction between biological system changes and sleep. The literature on biological rhythms shows that sleep has served as a significant experimental variable in that area. The chapter outlines the increasing role of chronobiology in sleep research and a brief review is given.

381. Webb W. B. (1985). Experiments of extended performance: Repetition, age and limited sleep periods. Behavior Research Methods, Instruments & Computers, 17(1), 27-36.

Four experiments on the effects of extended time periods without sleep on performance and on the effects of limited sleep within such periods, i.e. naps, are reviewed. The performance measures included subjective measures, attention/persistence tasks, continuous production, precision and cognitive tasks. Repeated periods of sleep deprivation did not result in decreased effects; older subjects tended to be more vulnerable to sleep loss and three different schedules of 4 hours of sleep within a 60 hour sleep deprivation period were limited in their ameliorative effects.

382. Webb W. B., Kaufmann D. A., & Devy M. C. (1981). Pilot fatigue and circadian desynchronosis. (Report No. TM-81275). Moffett Field, CA: National Aeronautics and Space Administration, Ames Research Center. (NASA Report No. N81-21045/2).

Pilot fatigue and circadian desynchronosis, its significance to air transport safety, and research approaches, were examined. There is a need for better data on sleep, activity, and other pertinent factors from pilots flying a variety of demanding schedules. Simulation studies of flight crew performance should be used to determine the degree of fatigue induced by demanding schedules and to delineate more precisely the factors responsible for performance decrements in flight and to test solutions proposed to resolve problems induced by fatigue and desynchronosis. It was concluded that there is a safety problem of uncertain magnitude due to transmeridian flying and a potential problem due to fatigue associated with various factors found in air transport operations.

383. Webb W. B., & Levy M. C. (1982). Age, sleep deprivation, and performance. Psychophysiology, 19(3), 272-276.

Men 18-22 and 40-49 yrs old were repeatedly given a battery of monitoring, persistence, and cognitive tasks over an extended period of sleep deprivation. The older subjects, who generally exhibited superior performance, were also more affected by the acute deprivation of sleep.

384. Webb W. B., & Levy M. C. (1984). Effects of spaced and repeated total sleep deprivation. Ergonomics, 27(1), 45-58.

Six young adult males were sleep deprived for 2 nights on five successive occasions at 3 week intervals. During the deprivation period they completed subjective ratings and performed on an extensive battery of tasks. Subjective measures and vigilance tasks showed substantial deprivation effects; the cognitively-demanding tasks were less affected. Where repetition of sessions resulted in changes, relative to sleep deprivation the effects were those of "sensitization" rather than "immunization".

385. Webster J. B., Kripke D. F., Messin S., Mullaney D. J., & Wyborney G. (1982). An activity-based sleep monitor system for ambulatory use. Sleep, 5(4), 389-399.

Wrist activity measured with a piezoceramic transducer was digitized and analyzed together with subjects' sleep/wake status to derive an optimal method for automatic computer sleep/wake scoring. Several algorithms for quantifying periods

of activity were considered, and an algorithm that summed changes in activity level over a 2-s interval was found most sensitive. A computer program for scoring sleep/wake from the resulting digital activity records was then developed, and parameters derived by comparison with subjects' sleep/wake status as determined by EEG. EEG and activity sleep/wake scores agreed 94.46% of the time. A further prospective test of the automatic scoring system with new data yielded agreement of 96.02%. Finally, the data collection and recording functions were implemented in a wearable microprocessor-base digital activity monitor.

The automatic scoring program was adjusted to use activity data collected by this monitor, and agreed 93.88% with EEG scoring. A prospective test with new data agreed 93.04% with EEG. Automatic scoring of activity data for sleep/wake is not only fast and accurate, but allows sleep to be monitored in non-laboratory situations. In addition, the score is objective and reliable, and free of scorer bias and drift.

386. Wegmann H. M., & Klein K. E. (1983). Circadian rhythms and sustained operations. In J. Ernsting (Ed.), Sustained Intensive Air Operations: Physiological and Performance Aspects. Proceedings of the NATO Advisory Group for Aerospace R&D (AGARD) Aerospace Medical Panel Specialists' Meeting at Paris, France April 1983. (NATO/AGARD Report No. CP-338, pp. 9-1 to 9-7). Loughton, Essex, United Kingdom: Specialised Printing Services, Ltd. (DTIC No. AD P002-985).

Sustained operations necessarily conflict with the circadian system in several ways: changes in the habitual work-rest cycle, shifts in meal- or sleep-timing, intense activity during night hours, sleep deprivation and disruptions of the normal synchrony between body functions and environment. When these rhythm disturbances affect performance, they become operationally significant. Their consequences are discussed and factors are described which influence the range of performance oscillation. Of particular operational relevance are motivation, sleep and physical exercise. Under certain conditions they can help to overcome deficits in performance and periods of diminished efficiency.

387. Wegmann H. M., Klein K. E., Goeters K. M., & Samel A. (1982). Studies on the flight medical aspects of the German Lufthansa non-stop route from Frankfurt to Rio de Janeiro, Part 1. (Report No. N82-20863/8). Washington, DC: National Aeronautics and Space Administration. (NASA-TM-76659).

The problem of crew size for regularly scheduled flights between Frankfurt and Rio de Janeiro is discussed. Factors affecting crew performance are examined, comparisons are drawn

to regulations of other countries and crew questionnaires and tests are presented.

388. Weitzman D. O. (1977). A survey of some human factor problems in night operations. (USARI Report No. RM-77-4). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

In the preliminary research on this subject, the physical, biological, and behavioral factors that affect night operation performance in the individual soldier were considered. Topics such as silent movement and camouflage, communication at night, and night target engagement constitute an important but separate body of knowledge and are not part of this plan. Emphasis in this report has been placed on current sensory, motor and cognitive factors in night mobility, the role of night vision, and the effect of fatigue and stress in night operations. In addition, individual differences in otherwise similar populations exposed to similar environmental conditions are considered.

This report provides background information potentially useful in planning future behavioral research on efficient utilization of the individual soldier during continuous and sustained night operations. Also considered in this light are the further evolution of night operations training, and the military operations that require weighing of the variability and limitations of the night warfare capability of a soldier.

389. West V., & Parker, J. F. (1975). A review of recent literature: Measurement and prediction of operational fatigue. (ONR Report No. 201-067). Arlington, VA: Office of Naval Research. (DTIC No. AD A008-405).

This report presents an overview, and selected bibliography of research dealing with the measurement and prediction of fatigue and stress. The impetus for this review is the need by military medical personnel for procedures which might be used to evaluate "operational fatigue" during periods of sustained operations. Of most interest are those techniques which can be easily implemented in a field setting. Two broad lines of investigation are being followed in current stress research. Investigators are generally attempting to identify either neurosensory or biochemical correlates of fatigue. Fatigue studies have failed to demonstrate conclusively a high positive correlation between subjective fatigue and work decrement. Performance can be maintained, within certain limits, in spite of limited sleep and high subjective fatigue.

While urinary excretion of proteins, electrolytes, and hormones seems to be related to fatigue, the relationship does

not appear to be consistently demonstrable, principally because of individual variability in the magnitude and direction of response, and because of difficulty in controlling variables not under study such as circadian rhythms, climatic conditions, and food and fluid intake. It has been suggested that a fruitful area of research might be to seek other metabolites in the urine originating from tissue catabolism which would reflect more specifically stresses of various origins and fatigue in various stages.

Some success may be in the offing in identification of neurosensory correlates of fatigue. Factor analysis of critical flicker fusion can distinguish meaningful phases of a long-term variation of cortical activity, and blink measurement may be a reliable index. Blink value, an indicator of autonomic system function, decreases with accumulation of fatigue. Moreover, these decreases follow trends similar to those shown by urinary excretion of total 17-hydroxy-corticosteroids. The blink technique is easily implemented, and evaluations can be performed with a high degree of accuracy within thirty seconds.

390. Westerdorf G. (1974). Desynchronization of circadian rhythm of exercise pulse rate following transmeridian flights. (DLR Report No. FB-74-39). Bonn-Bad Godesberg, Germany: Deutsche Forschungs-und Versuchsanstalt fur Luff-und Raumfahrt.

The responses of the diurnal cycle of pulse rate to transatlantic flights with a 6 hours time shift were studied in 8 untrained students during submaximal exercise. For this purpose the subjects were tested on a bicycle ergometer in 3 hourly intervals on two separate days before the outgoing and on days 1, 3, 5 and 8 following the outgoing and the homegoing flight.

The sojourn in the USA was 16 days. The results showed a significant desynchronization of the diurnal cycle of pulse rate after the transmeridian flights with an average readaptation time of five days. No distinct differences were observed with respect to the direction of flight.

391. Wever R. (1969). Untersuchungen zur circadianen periodik des menschen mit besonderer berucksichtigung des einflusses schwacher elektrischer wechselfelder. (Forschungsbericht Report No. W 69-31). Seewiesen und Erling-Andechs: Max-Planck-Institut fur Verhaltensphysiologie.

In a special underground bunker, circadian rhythms of 108 human subjects have been studied, in complete isolation from the environment. It has been shown that these rhythms can be influenced, not only by light but especially by an electric 10-

cps-field, and this according to a rule. In addition to period values and to some other rhythm parameters, the tendency towards internal desynchronization depends on the respective environmental conditions. The significance of the results obtained are discussed with regard to a special hypothesis of circadian rhythms, and considering the practical aspects of the influence of weak electro-magnetic fields on human beings, proven for the first time by the experiments mentioned.

392. Weybrew B. B. (1971). Submarine crew effectiveness during submerged missions of sixty or more days' duration. (USNSMRL Report No. 686). Groton, CT: US Naval Submarine Research Lab, Submarine Base. (DTIC No. AD 740-796).

The primary objective of this study was to integrate that segment of the literature of submarine psychology which focuses upon the major factors affecting submarine crew-member effectiveness during prolonged submergence. First, the most significant submarine stressors were delineated together with the specific adaptive processes correlated with them. These were found to be: confinement, revitalized air, flattening of circadian rhythms, threat of hyperbaric exposure and sleep deprivation. Performance decrements, incidence of debilitating morbidity (including psychopathology), and decompensatory trends in crew morale appeared to be minimal during long cruises.

In general, the impression from this integrative review of this rather specialized literature is that the habitability situation in the submarine service continues to be optimal, in part because of the effective psychiatric screening procedures in force, but also as a result of the quality of leadership demonstrated by the officers and petty officers making up the crews of the submarines in the fleet.

393. Whitehurst L. R., & Schopper A. W. (1980). Aeromedical aspects of CH-47C helicopter self-deployment: Operation Northern Leap. (USAARL Report No. 80-1). Fort Rucker, AL: US Army Aeromedical Research Laboratory.

In August 1979, the US Army accomplished its first transatlantic helicopter flight. Four CH-47C cargo helicopters departed Fort Carson, Colorado, and landed in Heidelburg, Germany, with intermediate stops in Iowa, Pennsylvania, Maine, Canada, Greeland, Iceland and England. A flight surgeon accompanied the mission to provide medical support and assess aircrew workload, stress and fatigue. Direct observation, interviews and questionnaires were used to gather data.

Respiratory infections were experienced by approximately 50% of the mission crew during the 14-day journey. These were

attributed to wide climate variations and inadequate crew rest during the first half of the mission. Daily pre-flight questionnaires showed highest levels of stress occurred at the start of the mission and decreased to a constant level once the mission was underway. Daily post-flight data demonstrated that cockpit workload increased appreciably with deterioration of weather during the latter part of the mission. Time at the flight controls and mission conditions during flight were found to be the greatest contributors to pilot fatigue; whereas, crew chiefs reported frequent time zone changes and poor facilities at stopover points to be their greatest causes of fatigue.

The results demonstrated the feasibility of self deployment and the need for medical support of such missions.

394. Williams H. L., & Lubin A. (1967). Speeded addition and sleep loss. Journal of Experimental Psychology 73(2), pp. 313-317, (USNHRC Report No. 66-16). San Diego, CA: US Naval Health Research Center.

The effect of 2 nights of acute sleep deprivation on experimenter-paced addition tests was to impair speed but not accuracy. Impairment was, roughly speaking, a multiplicative function of speed load (time per addition) and amount of sleep loss. If sufficient time per addition was allowed, there was no impairment up to 2 nights of sleep deprivation. The most sensitive of several experimenter paced tasks was one in which input and output requirements were held constant while the number of adding operations was increased. This finding implies that cognitive speed is especially vulnerable to drowsy states.

395. Wolfe J. W., & Brown J. H. (1968). Effects of sleep deprivation on the vestibulo-ocular reflex. (USAMRL Report No. 766). Fort Knox, KY: US Army Medical Research Laboratory. (DTIC No. AD 566-750).

Sixteen young adult men were deprived of sleep for a period of 24 hours in an attempt to assess possible interactions between sleep mechanisms and the vestibular system. Ss were given a pre- and post-test consisting of trials at angular accelerations of 8 degrees/sec sq and 24 degrees/ sec sq. Following sleep deprivation, Ss showed a significant increase in fast-phase frequency at 24 degrees/ sec sq, and a nonsignificant increment at 8 degrees/sec sq. Slow-phase output reflected a significant decrement at 8 degrees/sec sq, but no significant decrement at 24 degrees/ sec sq. Subjective latency estimates of stimulus onset showed no significant changes for either 8 degrees or 24 degrees/sec sq. Discussion centers around possible physiological mechanisms related to sleep and vestibular responses.

396. Wopjtczak-jaroszowa, Makowska Z., Rzepecki H., Babaszkiewicz A., & Romejko A., (1978). Changes in psychomotor and mental task performance following physical work in standard conditions and in a shift-working situation. Ergonomics, 21(10), 801-810.

Ten shift workers and 43 students were tested on a battery of psychological tests at different times of day within prolonged sessions of activity. It was shown that performance levels were determined by three factors: circadian fluctuations, elapsed time since the beginning of a session, and physical work done prior to testing. Visual-motor coordination was enhanced by the latter, but efficiency at purely mental tasks was degraded.

397. Woodward D. P., & Nelson P. D. (1974). A user oriented review of the literature on the effects of sleep loss, work-rest schedules, and recovery on performance. (ONR Report No. ACR 206). Washington, DC: Office of Naval Research. (DTIC No. AD A009-778).

This review provides a brief systematically organized account of the information from the scientific literature on the effects of sleep loss and work-rest schedules on performance. The orientation is practical, but consistent with the available data. A brief narrative description and a series of summary statements about the effects of sleep loss and work-rest schedules on human performance as they apply to operational settings is presented. Recovery from sleep loss effects as well as costs related to sleep loss effects are discussed briefly. Suggestions for future research are presented.

398. Wright J. E., Vogel J. A., Sampson J. B., Patton J. F., & Daniels W. L. (1980). Physiological work capacity and performance of soldiers following transatlantic deployment. (USARIEM Report). Natick, MA: US Army Research Institute of Environmental Medicine. (DTIC No. AD A090-450/8).

A 1977 survey obtained information on the effects of rapid transatlantic deployment on the health and operational effectiveness of troops. Information could be provided only on mental and cognitive functions which have been studied in commercial travelers and aircrew personnel. However, no data were available on physical work performance capacities. The authors set out to define the scope and determine possible remedies for this critical combat readiness problem. This paper discusses a survey which was conducted to study the effects of translocation (jet-lag) on the ability of infantry soldiers to perform heavy physical work.

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399. Zukhar V. P. (1968). Sleep and its limitations in long spaceflights. (Report Nc. JPRS-47398). Paper for the 3rd International Symposium on Basic Envircnmental Problems of Man in Space, USSR. Translation from various Russian conference papers, held at Geneva, 19-22 November 1968.

The main spaceflight factors that may significantly alter the sleep patterns of man and influence the duration and phase correlation of sleep include the following:

1) Weightlessness and related changes in the nature of the information arriving from the proprioceptive and exteroceptive receptors and vestibular apparatus;
2) Hypokinesia and hypodynamia, which are severe complications of weightlessness and confinement to the limited living space available in spacecraft;
3) Nervous and emotional strain caused by the dangers, responsibilities, and unusual nature of spaceflight;
4) Limited range of activity, meager information, and montonous surroundings;
5) Changes in the circadian rhythms, light, air temperature, noise background, etc.

Data are presented on an investigation of sleep under conditions simulating spaceflight. Some methods for physiological control of sleep patterns are suggested.

The comparative effectiveness of various ways of organizing the sleep and rest of astronauts during long spaceflights is evaluated.

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